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RESEARCH STATION
CHESHUNT, HERTS**

ANNUAL REPORT
(THIRTY-SEVENTH YEAR)

1951

**NURSERY & MARKET GARDEN INDUSTRIES'
DEVELOPMENT SOCIETY, LIMITED**

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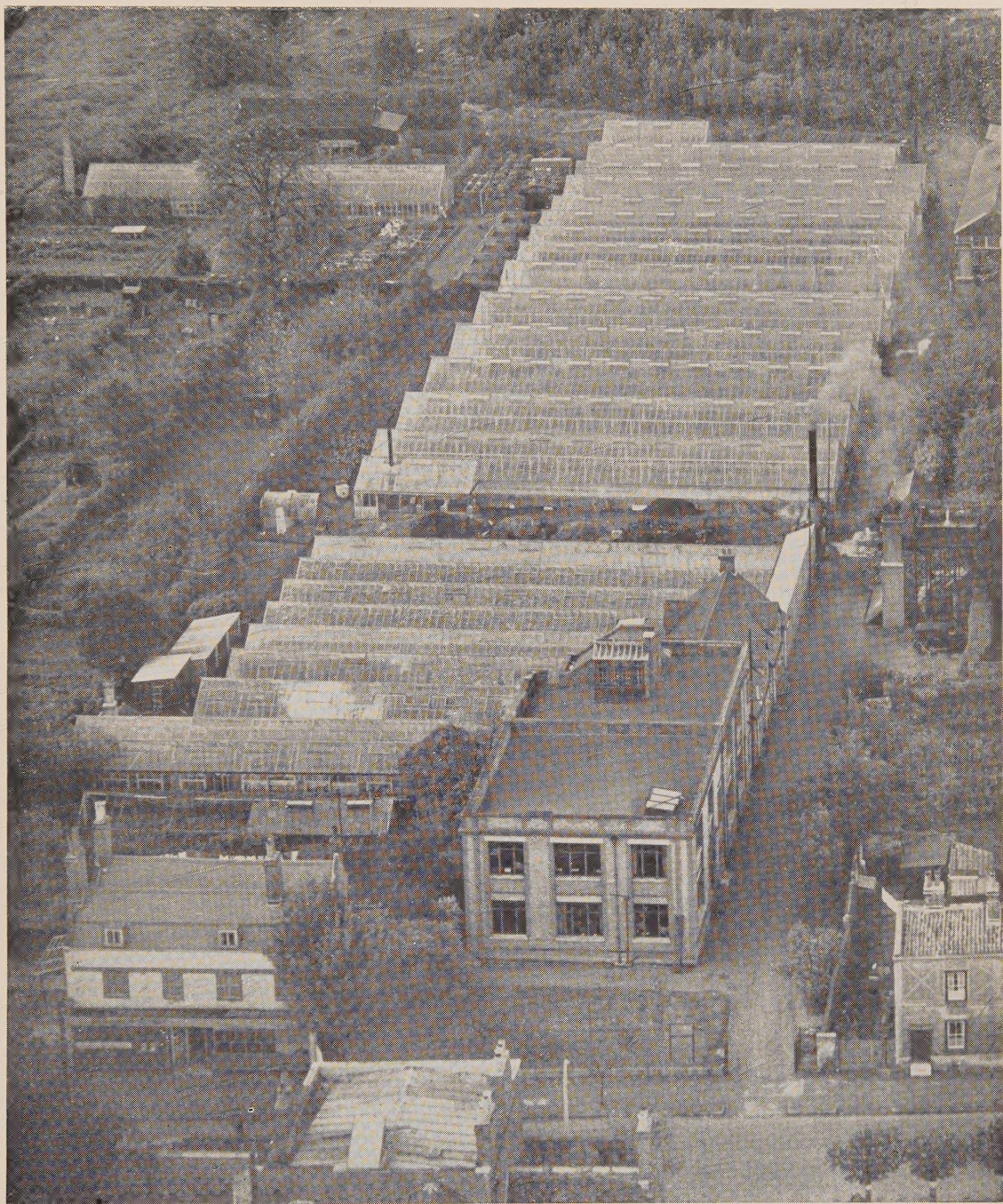
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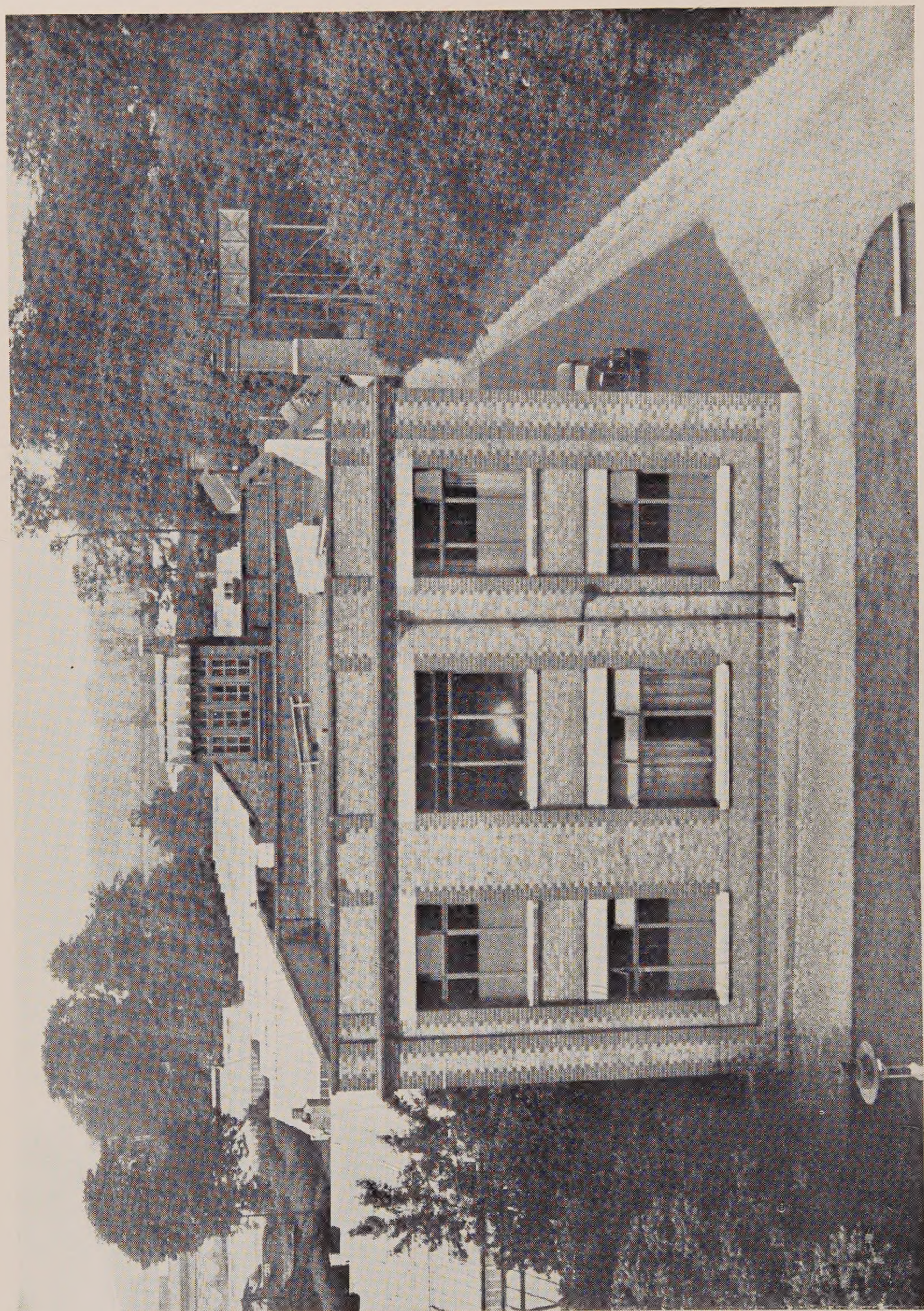
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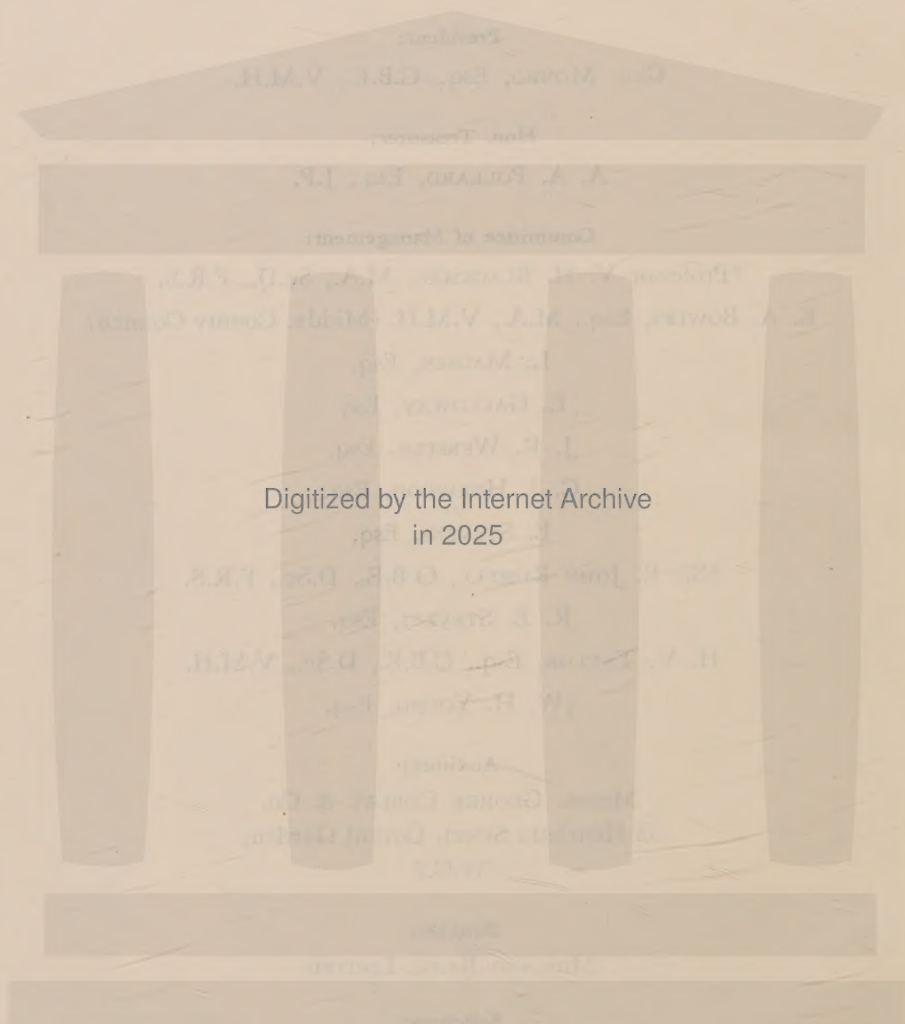
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Nursery and Market Garden Industries' Development Society, Limited

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TABLE OF CONTENTS

	Page
INTRODUCTION	9
OBITUARY	13
I. EXPERIMENTAL RESULTS OF 1951	
1. Tomatoes	14
2. Cucumbers	18
II. PLANT DISEASES	
1. Brown Root-rot of the tomato	22
2. <i>Didymella</i> stem rot	26
3. Fungicides:	
(a) Laboratory investigations	29
(b) Preliminary investigations of Fungicides for the Control of Cucumber Mildew	30
4. Virus Diseases:	
(a) Heat Treatment of Tomato Seeds	32
(b) Chrysanthemum Mosaic Disease	37
III. ENTOMOLOGY	
1. Red Spider Mite	41
2. Some effects upon Red Spider Mite of Bisdimethyl Phosphorous Anhydride	49
3. Tomato Leaf-miner	51
4. Insecticides:	
(a) Laboratory investigations	54
(b) Red Spider Mite Control in glasshouses	55
IV. CHEMICAL INVESTIGATIONS	
1. The Properties of some Urea-formaldehyde Materials in Relation to their possible use as Nitrogenous Fertilizers	56
2. Steam Sterilization Studies	67
3. The effects of some Acute Mineral Deficiencies on Perpetual-flowering Carnations	78
4. Lime-induced Manganese Deficiency in Glasshouse Roses	81
V. PLANT PHYSIOLOGY	84
VI. GROWERS' NOTES	
1. <i>Didymella</i> Stem Rot of the Tomato	85
APPENDIX	
A. Publications	88
B. Manurial treatments	93
C. Manurial treatments	95
D. Cultural operations	95
E. Meteorological Records 1951	96
Diagram showing arrangement of Experimental Plots, 1951.	

INTRODUCTION

The work of the Experimental and Research Station continues to make steady progress. The congested state of the laboratories is unfortunate and members of staff are to be congratulated upon the excellence of their work under very difficult conditions. A site for the new Research Station has been secured near Littlehampton in Sussex and it is hoped that its development will be rapid and provide an early solution to our difficulties.

GLASSHOUSE EXPERIMENTS

Soil Blocks

The relative effect of raising young plants in pots and soil blocks has been investigated further and in general crop yields have been in favour of the soil-block plants. Plants planted in the usual manner were compared with those planted in the bottom of shallow trenches, which gradually filled up as the season advanced. No differences in yield was observed where pot plants were used. The yield from soil-block plants planted in the trenches was lower, however, and it seems that the harder type of plant from the 3-in. pots was more suitable for planting in the wetter soil, for it was observed that in our type of land, the soil in the trenches remained wet longer than the surface of the surrounding ground. Some soil block plants were stood on top of the soil and earthed up at the sides. After a time the soil was washed away to expose the roots. These became very hard and green and it was noticeable that they were remarkably free from disease. This method may have some application on nurseries where the top of the root system invariably suffers from root rot. Crop yields from these plants equalled those of the controls.

These experiments confirmed the value of soil blocks in tomato propagation—a method which has certainly come to stay.

Deficiency Experiments

The deficiency experiments continued to give the same results regarding Blotchy Ripening of tomato fruits as in the past.

Soil Sterilization

The effect of injecting "D.D." into the soil was compared with that of steam sterilization. Both treatments controlled the Root Knot eelworm, *Heterodera marioni*, but the yield from the "D.D." plots, 50.98 tons per acre was less than that from the steamed plots, 55.39 tons per acre. This compares unfavourably with Chloropicrin tested in 1950, which gave approximately the same yield as that produced by steam sterilization.

Fertilizers

The experiment started in 1947 to determine the effect of omitting lime and phosphate from the tomato fertilizer treatment was continued for the fifth year. During the four previous years there was practically no difference in yield between the four treatments, but this year the plots from which lime and phosphate respectively were omitted produced 51 tons per acre, that receiving neither lime nor phosphate produced 54.76 tons per acre and the control plot 60 tons per acre. These results cannot be interpreted at this stage, but it is possible that the omission of lime and phosphate is beginning to have an effect.

Tomato Variety Trials

In the variety trials the new variety Potential attracted a great deal of attention and is being tested by growers all over the country in 1952. Others which seemed promising were Delicious, Corleys and Dufferns Seedling, the last of which produced the highest yield in June of 1.27 lbs. per plant.

Cucumbers

In the cucumber experiments a complete control of Root Knot eelworm, *Heterodera marioni*, was obtained by steam sterilization followed by injection of the soil with "D.D."

The introduction of an inert barrage underneath the beds once more emphasised the importance of a clean base because when the beds were placed on a solid brick base the crop yield rose from 69 tons per acre to 77.5 tons per acre.

A spacing experiment showed that the normal method of planting cucumber plants 2 ft. apart in the beds was correct and produced the highest yield.

PLANT PATHOLOGY

Didymella Stem Rot

A mild attack of *Didymella* Stem Root occurred on the Station Nursery. It was confined to houses at the western end and spores were trapped near the affected houses. No evidence was obtained from observations during this attack that straw mulches favoured the spread of the disease.

Cultures made from the stems of wilted plants showed that the fungus may penetrate up the interior of the stem for 10 to 16 ins. above the visible lesion. This fact obviously makes treatment of lesions to destroy the fungus very difficult.

In an experiment in which spores were introduced into the soil at varying depths, no infection resulted when they were buried 4 ins. deep. One plant out of five became infected when they were covered with 2 ins. of soil and all five were diseased when the spores were applied to the soil surface.

Further experiments have been carried out to find a method of isolating *Didymella lycopersici* from soil heavily infected with other organisms particularly species of *Penicillium*. Firstly, materials were tried which might selectively inhibit *Penicillium* spp. in poured plates and secondly, attempts were made to remove *Penicillium* but not *Didymella* from soil suspensions by filtration through sand. The most successful method found is to plate soil suspensions on a special low carbohydrate medium and incubate at a low temperature. A large proportion of the *Didymella* present develops even in competition with abnormally high concentrations of *Penicillium* and other fungi, and *Didymella* colonies may be isolated by subculture in green tomatoes.

Tomato Root Rot

In continuation of the investigation of tomato root rot, the microfloras of the soil, rhizosphere soil and root surface of tomato plants in steamed and unsteamed plots in the glasshouses have been studied. Bacterial numbers in the rhizosphere soil were generally higher than those from soil more distant from the roots, and in both cases samples from the unsteamed plot gave the higher counts. Numbers of bacteria isolated from the root surface were approximately equal from plants in steamed and unsteamed soil. Fungal numbers in the rhizosphere were higher, when compared with isolations from soil in the steamed soil, but in the unsteamed plot they showed a slight drop. On the root surface there were three times as many fungi from plants in unsteamed soil as on roots from steamed soil.

Of the species isolated, *Colletotrichum atramentarium* was frequently found on the root surface from June onwards, but occurred only rarely in the soil. The grey fungus K, previously reported as associated with root rotting of tomato, was frequently isolated from the soil though not in large numbers, but it did not occur in the rhizosphere soil until August and was only rarely isolated from the root surface. *Myrothecium roridum* occurred commonly in unsteamed soil and rhizosphere, but was less abundant in steamed soil. *Trichoderma viride* occurred more frequently in the rhizosphere than in the soil and was most frequent in the rhizosphere of plants in steamed soil. It was also more abundant on the root surface of plants grown in steamed soil. Species of *Fusarium* were more abundant from unsteamed than steamed soils, but in the rhizosphere soil and root surface flora this position was reversed, larger numbers being recorded from plants in the steamed soil. Species of *Penicillium* were abundant in steamed and unsteamed soil and also in the rhizosphere, although in the latter they tended to be fewer in proportion to the total numbers isolated.

Mosaic Diseases

The virus investigations have dealt with chrysanthemum mosaic and certain curative heat treatments. Floral and foliar symptoms of chrysanthemum mosaic are described for a number of varieties. Other host plants and symptoms are listed. The heat treatment work concerned tomato

and lettuce seed. In each case there does not appear to be much chance of cleaning seed badly infected with virus but in autumn most infected lettuce seedlings can be rogued within one month at the tray stage.

ENTOMOLOGY

Observations have been recorded upon the longevity and reproductive capacity of the adult summer forms of the Red Spider mite under differing environmental conditions, relating to excess and lack of moisture, abundance or lack of food, and alterations in the source from which the food is obtained.

Some information has been obtained upon the method of oviposition and the effects of excess and lack of moisture upon viability of the eggs.

Some preliminary experiments were carried out to test the effect of bis-(bis-dimethylamino) phosphonous anhydride upon the adult mites.

Flies of Tomato Leaf-miner (*Liriomyza solani* Her.) reared from larvæ mining in cucumber leaves oviposited readily upon tomato plants, and their progeny were reared to maturity.

Moist surroundings appeared to favour successful emergence of flies from the puparia: the flies reached maturity within puparia kept under dry conditions at a constant temperature of 80° F., but the emergence-caps of the puparia failed to open, and the flies were unable to effect their escape.

Development failed to take place in puparia which were subjected to a constant temperature of 35° F. shortly after their formation by the full-fed larvæ; in older puparia kept at this temperature for long periods of time, the insects, at least in some cases, developed to maturity after the puparia had been exposed to a temperature of 80° F.

Studies of the British Thysanoptera have been continued, the results of which will be published elsewhere.

INSECTICIDES AND FUNGICIDES

Red Spider Mite

Laboratory investigations of the toxicity of chemicals to eggs of the glasshouse Red Spider mite *Tetranychus telarius*, have been continued, and glasshouse trials have been made to determine the practical value of certain compounds for controlling this pest. Many new compounds have been synthesised in the laboratory during these investigations.

Certain of the chlorine substituted phenyl benzenesulphonates appear promising as acaricides for the control of the glasshouse red spider when distributed as aerosols, although laboratory assays of their ovicidal properties indicate that none of them are as active as azobenzene against eggs of Red Spider. Control of the mites by these compounds is slow, and although it has been claimed that control of mites is due to the persistence of ovicidal action, the effect on adult mites being negligible, results obtained so far at Cheshunt do not confirm this entirely.

Sciarid Flies

Experiments have shown that the larvæ of certain sciarid flies which attack the roots of cucumbers and other plants are very sensitive to parathion, but the most satisfactory concentration for application to cucumber beds has yet to be determined. Concentrations of 0.001 per cent. proved effective in laboratory and pot trials and good results were obtained in one trial in which the beds were watered with 0.0025 per cent. parathion. Provided the absence of the highly poisonous compound in the fruit is confirmed by further work, parathion may prove of considerable value against this pest.

Cucumber Mildew

In view of the increasing prevalence of cucumber mildew (*Erysiphe cichoracearum*) comparative trials have been made with some of the newer fungicides for its control. 2:3-Dichloro-1:4-naphthaquinone gave the most effective control but will probably prove too toxic to plants. Zinc ethyl bisdithiocarbamate was also promising but not quite equal to the standard copper oxy-chloride-petroleum emulsion spray. Two glyoxalidine preparations tested were highly toxic to plants.

Quinonoid Compounds

Laboratory investigations of the fungicidal activity of quinonoid and related compounds have been continued and a number of those most toxic to fungi have been tested to determine their effect upon living plants.

SOIL CHEMISTRY

Mineral Deficiencies

Extended experiments have confirmed that sulphur applied at 4 ozs. per sq. yd. will correct the characteristic chlorosis due to manganese deficiency in roses. Early retardation of growth occurs in one variety but this effect disappears comparatively early in the growing season.

Deficiency studies on the perpetual flowering carnation show, as for other subjects, two considerations of importance. One is the variety and the other is the time in the life of the plant at which the particular deficiency begins to operate.

Soil Nitrogen

The study of ammonification and nitrification in soil after steam sterilization has been continued. Ammonia production in a plot sterilized in the experimental houses in November 1950 and subsequently left undisturbed has been compared with that in an adjacent plot dug over weekly to a depth of 9 ins. Neither plot was flooded nor planted. In the undisturbed steamed plot the ammonia concentration after the usual initial rapid rise persisted at a high level up to 10 months after steaming. On the other hand in the steamed and dug plot ammonia concentration increased rapidly initially and then slowly until the sixty-fifth day after steaming. Thereafter it fell slowly and by the one-hundred-and-seventh day was at a low level, its disappearance being accompanied by rapid nitrification. The soil surface in the glasshouse is exposed to any fortuitous aerial infection and it is probable that the mixing involved in digging effectively contaminated the main body of the soil with nitrifying organisms thus bringing about the more rapid decline in ammonia concentration in the dug plot. In contrast the dry conditions obtaining at the surface of the undisturbed steamed plot would not provide a suitable environment for the multiplication of nitrifying organisms, infection is slow and ammonia persists for long periods.

The possibility that nitrification occurs at the surface of the undisturbed steamed plot has been examined. It was found that there was an accumulation of water soluble solids including nitrates at the surface, concentrations falling rapidly with increasing depth. Ammonia on the other hand, which is held firmly in the base exchange complex, was uniformly distributed in the upper 9 ins. and provides evidence that no active nitrification was occurring. A similar accumulation of water soluble solids at the surface was found in an undisturbed, unsteamed plot while in the steamed plot which was dug over weekly there was no time for this effect to become pronounced and nitrate was uniformly distributed in the upper 9 ins.

These results may be explained on the assumption that evaporation of water from the exposed soil surface creates an upward movement of water from the subsoil which in turn transports soluble salts to the soil surface. This view was supported by experiments in which new horizontal and vertical soil surfaces were exposed to the atmosphere, subsequent analysis after a suitable interval showing high concentrations of nitrates in the surface layers.

The nitrifying capacity of the soil from the undisturbed steamed plot at different depths, four months after steaming was studied by incubation with ammonium sulphate. The results indicate that reinfection of steamed soil with nitrifying organisms was taking place both from the surface in a downward direction and from the subsoil in an upward direction.

Urea/Formaldehyde

The preparation and testing of urea-formaldehyde compounds, referred to in the Annual Report for 1950, has been continued. Synthetic materials of this type have been suggested in America as a possible addition to the existing range of nitrogenous fertilizers. The results of laboratory nitrification tests are now reported. For any one method of preparation the main factor controlling mineralization of the product when added to the soil appears to be the ratio of urea to formaldehyde. The amount of soluble nitrogenous compounds formed in the reaction and the maximum availability of the nitrogen when added to the soil both increase with this ratio. In the early stages mineralization is closely related to the soluble nitrogen content, and is therefore greatly influenced by the method of preparation. Thus when the reaction mixture is allowed to solidify and residual water is removed by evaporation the product generally contains unreacted urea and other soluble nitrogenous compounds. Mineralization of such materials commences rapidly in the soil. If, however, the solid products are separated from the reaction mixture by filtration there is, in absence of soluble nitrogenous compounds, a period of lag before mineralization commences. The rate of decomposition can thus to some extent be controlled by the conditions of preparation of the urea-formaldehyde products, but it has not yet been found possible to combine the desired characteristics of low rates of mineralization with high maximum availability of the nitrogen in the soil.

Hoof and Horn

The rates of decomposition and the availability of the nitrogen of 41 samples of hoof and horn materials are under investigation. The samples include hoof and horn both separately and together, with and without preliminary heat treatment ("calcining") by the manufacturers. It is already apparent that these commercial samples possess greater uniformity in composition and properties than did the bone meal samples previously investigated by similar methods.

PLANT PHYSIOLOGY

Dutch Light Temperatures

Observations on air and soil temperatures in the open and under Dutch lights, and also of wind speed in the open, have been continued in collaboration with the Agricultural Branch of the Meteorological Office on the site alongside the meteorological plot. Maximum and minimum indicating soil thermometers at three depths are now in use and recording instruments at two depths were installed at the end of the year.

Root Studies

A glass-sided box and glass-lined trench have been used for observations on the growth of tomato roots under normal commercial glasshouse cultural conditions. Information has been obtained on the inter-relations in time of the development of the aerial portions and the roots. The considerable volume of data is in process of analysis. A partial soil-block survey of the roots in the box was made for comparison with the data on root distribution in a vertical plane obtained from the glass sides.

A new technique is being developed for the analysis of the soil atmosphere using a micro-gas analysis apparatus. It is hoped that this will afford data on the gaseous environment at different distances from the roots.

Further tests have been made of soil tensiometers using different grades of filter candles. A compensating manometer is being tried out whereby a minimal amount of water is allowed to escape to the soil in the development of negative pressure. Such an instrument is very desirable in investigations on the amount of water available in the soil.

OBITUARY

It is with sincere regret that we record the death on November 16th of our President, Mr. George Monro, C.B.E., V.M.H., in his seventy-sixth year. Mr. Monro was an outstanding personality who served his country in so many ways that he made friends in every walk of life and in many countries of the world. Although horticulture was his first love he did splendid work in the Headquarters Detachment of the Metropolitan Special Constabulary during the first World War, and was awarded first the O.B.E. and then the C.B.E. He was a trustee of the Royal Gardeners' Orphans' Fund and when he died he was Honorary Treasurer of the Automobile Association.

To horticulture he gave all he had. As joint managing director of George Monro Ltd., of Covent Garden and Waltham Cross, he possessed a profound knowledge of commercial horticulture in all its aspects. He served on the Council of the Royal Horticultural Society from 1924 and was Honorary Treasurer from 1938 to 1942. He was Chairman of the Joint Dianthus Committee, the Joint Perpetual-flowering Carnation Committee and the Joint Dahlia Committee and Vice-Chairman of the Narcissus and Tulip Committee. He was President of the British Carnation Society and later became first President of the British National Carnation Society.

He was also a founder and president of the British Florists' Federation which became later the British Flower Industry Association.

All these appointments bear testimony to his knowledge and organising ability and to the respect in which he was held by his fellow horticulturists.

Our President was a regular attender at all our meetings: his dignified and genial figure was always to be seen at our Members' Day gatherings over which he presided.

To the Research Station he was a constant tower of strength: his wise and kindly counsel, his disarming smile and readiness to help at any time will be greatly missed.

He loved horticulture and horticulture loved him.

EXPERIMENTAL RESULTS OF 1951

I. TOMATOES

The practice of grading the tomato fruits from the experimental plots, adopted in 1921, was continued:—

- A. "Pinks" number 5 to 7 and "Pink and White" 8 to 10 to the lb. These are the best quality of fruit in size, shape and colour; "Pinks" being slightly larger than "Pink and Whites."
- B. "Whites." These fruits are of good colour but smaller than "Pink and White."
- C. "Blues." This grade consists of fruits of good colour but larger and more irregular in shape than Grade A.
- D. "Roughs." Small mis-shapen fruits about the size of cherries.
- E. Blotchy fruits which ripen irregularly.
- F. Fruits showing Blossom End Rot.
- G. Fruits showing the lesions of Streak Diseases.
- H. Fruits showing "Green Back."

(a) Soil Blocks versus Pots

In house 3, the soil of which was sterilized with formaldehyde for the 1950 crop, an experiment was arranged comparing the crop (Downes Seedling) from plants raised in the usual size 60 pots, with that from plants raised in soil blocks. The average yield was identical, being 45·36 tons per acre as against 45·07 tons per acre.

In other plots plants out of "60" pots were planted in ridges, 6 ins. high, while in others, plants raised in soil blocks were stood on top of the ground, and soil thrown up against the sides to earth them up. The crop from the plants on ridges 47·12 tons per acre was almost identical with that in soil blocks standing on top of the soil—46·29 tons per acre. The results are given in Table II.

In house 9, where the soil had been steam sterilized during the winter and Ailsa Craig was the variety the plants in two plots had been raised in size 60 pots, and those in the other two plots in soil blocks.

The soil blocks produced a yield of 53·26 tons per acre and the pots 49·18 tons per acre—a result definitely in favour of soil blocks. The results are given in Table II.

In house 10, steam sterilized during the winter, the variety Bruinsma was grown. There were two control plots where plants raised in "60" pots were planted in the usual way. The average yield was 57·99 tons per acre.

In six other plots, the plants were planted in trenches 4 ins. deep, to keep the roots moist during the early stages. In two of these plots plants were raised in "60" pots and planted in the bottom of the trench in the usual way. The yield was approximately the same as that of the previous two plots where the plants were planted on level ground, namely 58·45 tons per acre. In two other plots soil blocks were planted in the bottom of trenches, and in the remaining two plots soil blocks were planted so that half the block remained above the bottom of the trench. Yields were lower here, being 55·94 and 53·20 tons per acre. This suggests that the harder type of root produced in pots is more suitable for planting in trenches than the finer roots in soil blocks. It was noticed in our type of soil that the bottoms of the trenches remained very wet. The results are given in Table III.

The results of these experiments confirm the value of soil blocks in tomato propagation. They also suggest that there may be some benefit to be derived from planting on top of ridges, which leads to exposure of the base of the stem and the top of the root system to the air during the growing season. In this way that part of the root system which is most susceptible to fungal attack is hardened and becomes more resistant.

The practice of planting in trenches, however, is hardly to be recommended for the heavier types of soil.

(b) House 4: Deficiency Plots

The deficiency experiments in house 4 continue to yield the same kind of result with regards to blotchy ripening of the fruit. The unmanured plant produced 12·35 per cent. and the plot deficient in potash 48·27 per cent. blotchy fruit. Only 0·44 per cent. occurred in the "no nitrogen" plot.

TABLE I
VARIETY: DOWNES SEEDLING. SOIL TREATED WITH FORMALDEHYDE

House	Plot	Treatment	Crop Yield in Lbs. per Plant					Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.		
3	1	Planted from pots in the usual way ...	0.85	2.38	1.25	1.31	0.65	0.16	6.60	45.36
	5	Ditto ...	0.25	1.87	1.61	0.99	0.42	0.15	5.29	
	2	Planted from soil blocks in the usual way ...	0.52	2.44	1.26	1.12	0.55	0.17	6.06	45.07
	3	Ditto ...	0.23	2.51	1.37	1.02	0.51	0.16	5.80	
	6	Ball from pots planted on ridges	0.43	2.30	1.64	1.01	0.53	0.11	6.02	47.12
	8	Ditto ...	0.79	2.41	1.39	1.09	0.61	0.09	6.38	
	4	Soil blocks stood on soil and earthed up at the sides ...	0.75	2.28	1.60	0.88	0.49	0.18	6.18	46.29
	7	Ditto ...	0.63	2.26	1.58	0.89	0.57	0.07	6.00	

TABLE II
VARIETY: AILSA CRAIG. SOIL STEAM STERILIZED.

House	Plot	Treatment	Crop Yield in Lbs. per Plant					Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.		
9	1	Planted from soil blocks ...	0.91	1.88	1.23	1.21	1.51	0.16	6.90	53.26
	3	" " " "	0.28	2.18	1.63	1.26	1.50	0.27	7.12	
	2	Planted from size 60 pots ...	0.36	1.96	1.41	1.22	1.42	0.29	6.66	49.18
	4	" " " " " "	0.14	1.77	1.52	1.13	1.36	0.36	6.28	

TABLE III
VARIETY: BRUINSMA. SOIL STEAM STERILIZED.

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.	Total			
10	3	Control. Planted from 60's in usual way ...	0-12	1-37	2-00	1-65	1-74	0-49	7-27	{ 55-25 60-72}	57-99	0-54 0-25
	8	" " " " 4 ins. deep. " " Plants from 60's	0-24	1-65	1-93	2-16	2-01	—	7-99			
	4	Trenches planted in the bottom ...	0-03	1-08	2-26	2-01	1-83	0-66	7-87	{ 59-81 57-08}	58-45	—
	7	Ditto " " " " " "	0-10	1-10	1-96	2-36	1-99	—	7-51			
	2	Trenches 4 ins. deep. Planted with soil blocks	0-12	1-21	2-00	1-78	1-70	0-43	7-24	{ 55-02 56-85}	55-94	0-26 0-27 0-26
	5	" " " " " "	0-03	0-80	2-18	1-95	2-52	—	7-48			
	1	Trenches, Planted with soil blocks, Blocks buried to half the depth ...	0-26	1-16	1-69	1-57	1-77	0-48	6-93	{ 52-67 53-73}	53-20	0-15 0-15
	6	Ditto " " " " " "	0-05	0-96	2-20	1-80	2-06	—	7-07			

TABLE IV
VARIETY: CORLEYS. SOIL TREATED WITH FORMALDEHYDE

House	Plot	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.			
4	1	C.A. without nitrogen	1.12	0.62	0.33	0.29	—	—	2.36	17.93	0.44
	2	Unmanured	0.91	0.73	0.39	0.24	—	—	2.27	17.25	12.35
	3	C.A.	1.02	2.48	1.39	1.34	—	—	6.23	47.34	1.61
	8	C.A. plus horse manure	0.90	2.50	1.83	1.21	—	—	6.44	48.94	3.11
	9	C.A. without phosphates	1.13	2.03	1.18	0.66	—	—	5.00	38.00	1.00
	10	C.A. without potash	1.04	1.20	0.59	0.36	—	—	3.19	24.24	48.27
	4	Leather waste	0.73	2.75	1.91	1.79	—	—	7.18	54.56	2.09
	7	"	0.89	2.77	1.90	1.60	—	—	7.16	54.41	1.82
	6a	2 in. gravel worked into top spit	0.23	1.55	1.35	0.84	—	—	3.97	30.17	0.27
	6b	4 in. "	0.53	2.17	1.88	1.21	—	—	5.79	44.00	0.34
	6c	6 in. "	0.57	2.19	1.81	1.09	—	—	5.66	43.02	0.53

TABLE V
VARIETY: E.S.5. STEAM STERILIZATION V. D.D.

House	Plot	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.			
8	1	Soil steamed	1.46	1.57	1.26	1.58	1.49	0.12	7.48	56.85 61.79 53.35 49.55	0.27
	4	"	1.09	2.04	1.70	1.86	1.28	0.16	8.13		0.37
	6	"	0.81	1.83	1.35	1.84	1.08	0.11	7.02		0.14
	7	"	0.90	1.81	0.91	1.74	1.06	0.10	6.52		0.45
	2	Injected with D.D.	1.07	1.47	1.27	1.56	1.30	0.13	6.80	51.68 51.00 46.51 48.71	0.28
	3	"	1.05	1.47	1.15	1.58	1.32	0.16	6.71		0.45
	5	"	0.51	1.76	0.97	1.50	1.13	0.25	6.12		0.18
	8	"	0.97	1.71	0.84	1.66	1.08	0.15	6.41		—

TABLE VI
VARIETY: E.S.5. SOIL TREATED WITH FORMALDEHYDE

House	Plot	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.			
5	1	Control for drip watering	1.15	2.13	1.69	1.01	—	—	5.98	45.45 48.79 46.21 42.71	0.33
	2	"	1.31	2.19	1.91	1.01	—	—	6.42		0.95
	7	Drip watering	1.08	2.64	1.68	0.68	—	—	6.08		3.46
	8	"	1.11	2.33	1.40	0.78	—	—	5.62		1.77
	3	Control for sulphur plots	1.12	1.86	1.85	0.92	—	—	5.75	43.70 38.84 41.42 44.38	0.87
	5	"	0.84	1.64	1.93	0.70	—	—	5.11		0.98
	4	1 lb. sulphur per square yard	0.85	1.86	1.88	0.86	—	—	5.45		0.36
	6	½ lb. " " "	1.07	2.20	1.93	0.64	—	—	5.84		0.85

This is unusual, and can only be accounted for by the fact that the soil had been steam sterilized in the winter and additional nitrogen rendered available.

Plots 4 and 7, to which leather meal is added each year, continue to crop well, the yield being around 54 tons per acre. The variety being "Corleys."

The results are given in Table IV.

(c) House 5: Drip Watering

In house 5, variety E.S.5, where the soil had been treated with formaldehyde during the winter, a drip watering system was tested against the ordinary method of watering. In this method most of the water was allowed to fall, drop by drop, on to the roots of each plant, but as feeding was carried out in the form of dry top-dressings, these were washed in by watering with a hose in the usual manner. The results given in Table VI were slightly in favour of the ordinary method.

In this house, also, the application of sulphur to the soil was continued. Control plots, receiving no lime, gave an average yield of 41.27 tons per acre. Where $\frac{1}{2}$ lb. of sulphur per sq. yd. was given the yield was 44.38 tons per acre, where 1 lb. of sulphate was applied the yield was 41.42 tons per acre.

(d) House 8: Steam Sterilization v. "D.D."

In 1950 this house was divided into eight plots, four being steam sterilized and four treated with chloropicrin. The results were highly satisfactory. Yields were high and there was no significant difference in yield from the two treatments.

This, year, chloropicrin was difficult to obtain so the soil treated with chloropicrin for 1950 was injected with "D.D." for 1951. The plots steamed for 1950 were steamed again for 1951. This year the variety grown was E.S.5.

Crop yields were high, but the "D.D." was not so effective as was chloropicrin in 1950. The steam sterilized plots produced 55.39 tons per acre, the "D.D." plots 50.98 tons per acre. Root knot eelworm, *Heterodera marioni*, however, was controlled successfully.

The results are given in Table V.

(e) Houses 11 and 12: The effect of omitting Lime and Phosphate from the Fertilizer Treatment

These experiments were started in 1947 and this year was therefore the fifth in this series. The results are given in Table VII.

The yield from the control plots averaged 60.04 tons per acre. The omission of lime and phosphate respectively reduced the yield to 51.15 and 51.30 tons per acre, but where both lime and phosphates were omitted the average yield was 54.76.

Although yields remain high, it is possible that the omission of these two substances is beginning to take effect.

(f) Variety Trials

Variety trials were continued in the Rose House; the results are given in Table VIII.

The soil was steam sterilized and all the varieties have given a high yield, there being nothing under 52 tons per acre. Four new varieties were tried for the first time, namely Potential, Giles, and Eagles from Guernsey, and Delicious. Of these Potential proved to be the most attractive. It resembles Potentate in habit, and actually produced more fruit than Potentate in June (namely 0.64 lbs. per plant against 0.22 lbs. per plant). The fruit is of good shape and colours well and has a good flavour. Delicious also produced good fruit, but the shape was not so good as many other varieties. Giles and Eagles cropped well and produced attractive fruit, somewhat smaller than Potential or Delicious. Once again Corleys behaved well, but it is a somewhat mixed variety which needs a good deal of selection. Dufferns Seedling gave the highest yield in June of 1.27 lbs. per plant and is an attractive variety.

2. CUCUMBERS

Following up the successful use of "D.D." in controlling the root knot eelworm, *Heterodera marioni*, in 1950 all the cucumber houses were steam sterilized and then treated with "D.D.", including the paths. The treatment was completely effective and at the end of the season no nodules

TABLE VII
VARIETIES: PLOTS 1 AND 4, DUFFERNS SEEDLING; PLOTS 2 AND 3 E.S.I. SOIL NOT STERILIZED.

House	Plot	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	Average Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Nov.	Total		
11	1	Standard treatment	0.29	1.41	2.81	1.39	1.64	—	7.54	57.30	1.73
	2	"	0.15	1.64	2.75	1.42	2.30	—	8.26	62.78	1.45
	3	No lime	0.09	1.53	2.76	1.33	2.04	—	6.75	51.30	2.38
	4	"	0.21	1.37	2.40	1.09	1.64	—	6.71	51.00	1.34
12	1	No phosphates	0.44	1.75	1.53	1.09	1.20	—	6.01	45.68	0.68
	2	"	0.36	2.05	1.78	1.60	1.70	—	7.49	56.92	1.07
	3	No phosphates and no lime	0.51	2.37	1.45	1.95	1.78	—	8.06	61.25	0.49
	4	"	0.41	1.85	1.71	1.34	1.04	—	6.35	48.26	0.62

TABLE VIII
VARIETY TRIALS. SOIL STEAM STERILIZED.

House	Plot	Variety	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening
			June	July	Aug.	Sept.	Oct.	Total		
Rose House	1	Delicious	0.48	3.02	2.19	1.47	1.23	8.39	63.76	3.34
	2	Potential	0.64	3.42	2.33	1.60	1.41	9.40	70.54	5.92
	3	Giles	0.27	3.12	2.91	1.63	1.33	9.26	70.38	5.51
	4	Clibran's Victory	0.45	2.73	3.44	1.69	1.25	9.56	72.66	5.11
	5	Freedom	0.46	2.21	1.81	1.43	1.02	6.93	52.67	5.06
	6	Bruinsma	0.50	2.05	3.59	1.51	1.44	9.09	69.08	3.30
	7	Corlys	0.96	4.10	2.07	1.72	1.38	10.23	77.75	2.36
	8	Dufferns	1.27	3.26	2.60	1.63	1.17	9.93	75.47	2.32
	9	Eagles	0.22	3.49	1.92	1.41	1.80	8.84	67.18	8.93
	10	Potentate	0.22	3.62	2.13	1.69	2.05	9.71	73.79	11.02

TABLE IX
VARIETY: BUTCHER'S DISEASE RESISTER

Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Total Flats per Ft.	
		Apr.	May	June	July	Aug.	Sept.	Oct.			Total
D1	Sand in base ...	5-19	7-07	8-33	7-08	4-59	3-77	1-69	37-72	56-58	1-18
2	Drip watering ...	7-44	12-01	10-44	10-66	5-94	4-39	1-94	52-82	79-23	1-65
3	Gravel in bed ...	5-10	7-72	8-53	9-81	5-35	4-11	2-07	42-69	64-03	1-33
4	Brick bed ...	5-60	5-37	2-45	3-85	4-27	3-66	1-38	26-58	39-87	0-83
5	Control ...	7-04	8-58	10-34	10-03	4-79	4-78	2-37	47-93	71-89	1-50
6	Clinker base ...	5-93	7-20	10-95	8-68	5-63	4-79	1-42	44-60	66-90	1-39
E1	Control ...	5-35	8-43	10-08	9-54	3-69	3-81	1-19	42-09	63-13	1-39
2	"	6-54	7-60	9-01	8-46	4-03	3-32	0-95	39-91	59-86	1-25
3	Drain pipes end open	4-79	7-08	9-31	6-97	5-28	4-52	1-29	39-24	58-86	1-23
4	Brushwood core	6-98	6-44	5-44	6-06	3-54	3-57	1-34	33-37	50-05	1-04
5	Drain pipes, ends closed	7-11	7-20	7-56	7-19	3-76	3-05	0-43	36-30	54-45	1-14
6	Gravel in base	7-22	7-03	6-35	6-85	3-11	2-78	1-43	34-77	52-15	1-09
F1	Control	6-20	8-33	7-73	7-23	2-38	3-89	3-64	39-40	59-10	1-23
5	Control, 2 ft. apart, one leader	7-46	7-53	6-49	7-02	3-61	3-68	2-09	37-88	56-82	1-18
2	Plants spaced 2 ft. 6 ins. apart, three leaders	3-54	11-97	8-97	7-66	3-06	2-54	2-05	39-79	42-45	1-24
3	" 2 ft. apart, three leaders	3-37	7-91	5-01	6-01	2-39	1-60	1-18	27-47	41-20	0-86
4	" 3 ft. "	4-82	9-78	7-70	9-75	5-35	5-19	2-98	45-57	41-67	1-43
6	Train laterals and sub-laterals downwards	7-24	7-41	6-19	7-40	3-03	2-48	2-91	36-66	54-99	1-15
G1	Brick base, flat bed	5-90	9-48	11-30	11-65	5-47	4-97	2-90	51-67	77-50	1-62
2	Plants spaced 1 ft. 6 ins. apart, one leader	4-46	8-73	5-00	6-01	3-07	2-45	1-35	31-07	56-82	0-97
4	" "	5-05	6-38	4-53	6-37	3-38	3-08	1-66	30-45	55-69	0-95
3	Control: 2 ft. apart, one leader	6-11	9-79	5-67	10-95	5-78	5-88	3-10	47-28	70-92	1-48
5	Plants spaced 2 ft. apart	4-76	9-37	8-89	8-61	5-32	4-83	2-99	44-77	67-15	1-40
6	Brick base, standard beds	5-24	8-89	12-58	10-69	5-40	3-74	3-00	49-54	74-31	1-56

were seen on the roots. Bees, however, were still a menace and caused a reduction in marketable fruit in the middle of the season.

It has been noticed for some years that there is an increasing tendency of the roots to grow downwards into the base and to develop less freely in the actual beds. It seemed possible that this was acting adversely on crop yield and so the effect of adding sand, clinker, and gravel to the base was tried on a small scale as a preliminary to larger experiments in the future. The addition of sand and gravel made little difference but a clinker base increased the yield to some extent. When, however, a solid brick base was laid under the beds and the roots prevented from entering the base the crop rose from 69 tons to 77·5 tons per acre.

In continuation of previous experiments the use of a central core of drainpipes or brushwood in the beds had little effect on the crop.

A spacing experiment in houses F and G gave interesting results. Plants were spaced 2 ft., 2 ft. 6 ins., and 3 ft. apart and allowed to develop three leaders instead of one only. Controls were spaced 2 ft. apart and allowed one leader. The three-leader method was obviously unsuitable. Fruiting was delayed while the plants were establishing themselves and the crop fell from the control yield of 56·8 tons per acre to about 42 tons per acre. Other plants were spaced 1 ft. 6 ins. and 2 ft. apart and allowed one leader. Here again the standard spacing of 2 ft. gave the highest yield, producing an average of 69 tons against 56·2 tons per acre from the closer planting.

This confirms the standard practice of spacing the plants 2 ft. apart and growing them on one leader.

The "drip" system of watering was tried again for the second year. During the early stages the plants became very pale in colour, and it was obvious that nitrogen was being leached out by the continual dripping of water in the same place. A dressing of nitrogen was applied and the plants were fed by watering with a liquid fertilizer through the "drip" apparatus. They quickly recovered and ultimately produced the highest yield of all the plots.

The results are set out in Table IX.



II. PLANT DISEASES

I. BROWN ROOT-ROT OF THE TOMATO

By P. H. WILLIAMS and M. H. EBBEN

Investigations on the microflora of the soil and tomato rhizosphere in the glasshouse have been commenced, to see if any differences could be found in the distribution of fungi previously reported as associated with brown root rot of the tomato.

The dilution plate method was used for isolating fungi and bacteria; dilution samples were plated on Waksman's medium, containing 1 : 15,000 rose bengal to prevent bacterial growth, for the identification of fungi, and on a soil extract medium containing 0.1 per cent. yeast extract, 0.1 per cent. glucose, and 0.05 per cent. K_2HPO_4 for the isolation of bacteria. Numbers of bacteria were counted but the different types isolated on the plates were not identified. Soil isolations were made from an aggregate of samples taken from 3-6 ins. below the soil surface level and 6-12 ins. distant from the tomato plants. The rhizosphere soil isolations, called the "outer rhizosphere," were obtained by shaking soil from the roots of plants which had been lifted for examination, shaking this soil in sterile water and then diluting and plating the resulting suspension. Isolations from the root surface, the "inner rhizosphere," were made by shaking roots, which had been brushed free of soil particles, in sterile water and diluting and plating the suspension. Isolations of fungi and bacteria from the soil and the outer rhizosphere were counted and recorded as numbers of colonies per gramme of dry soil, those from the inner rhizosphere both as numbers per gramme of air dry root and as numbers per square centimetre of root surface. Neither of the methods of recording numbers from the root surface was entirely satisfactory: the root weight increased considerably when thicker roots were used, and measurement of root surface area could not be very accurate due not only to irregular shape but also to the fact that where lesions were present the roots were often cracked and split, giving a larger surface area than could be measured. Since these different methods of recording the numbers of isolations were used for the root surface, no direct comparison could be made with the numbers isolated from the soil and outer rhizosphere. Isolations from all three sources were made at fortnightly intervals throughout the growing season from steamed and unsteamed plots in the glasshouse, starting in April, the soil having been steam sterilized the previous November.

The numbers of bacteria in the soil and the outer rhizosphere tended to decrease slightly towards the end of the season in both steamed and unsteamed plots, the decrease in numbers in the rhizosphere being more marked than in the soil. There was a wide range in the actual numbers isolated as shown below in Table I.

TABLE I
NUMBERS OF BACTERIA ISOLATED

	Millions per gm. of Dry Soil				Millions per square cm. of Root Surface	
	Soil		Outer Rhizosphere		Inner Rhizosphere	
	Steamed	Unsteamed	Steamed	Unsteamed	Steamed	Unsteamed
Range	36.7-105.4	34.8-281.6	37-127.5	38.8-190.8	0.76-4.4	0.52-4.42
Mean	59.1	76.4	80.6	98.5	1.62	1.92

Numbers from the outer rhizosphere were generally higher in the unsteamed plot than in the steamed plot. In the soil although the mean value for unsteamed soil is higher than for steamed soil there was a wider fluctuation than in the numbers from the outer rhizosphere (see Table II). Bacterial numbers recorded from the inner rhizosphere were higher in the steamed plot during the earlier part of the season, but later the numbers from roots in unsteamed soil rose sharply while those from steamed soil remained relatively steady. This is apparent in Table II where the ratio of number of bacteria in the unsteamed plot to number in the steamed plot rises towards the end of the season.

TABLE II
RATIO OF NUMBER OF BACTERIA IN UNSTEAMED PLOTS TO NUMBER IN STEAMED PLOT

	April		May		June		July		Aug.		Sept.		Oct.		Nov.		M'n
Soil	0.71	1.14	1.52	2.72	0.7	—	0.9	0.8	2.28	1.0	—	—	0.04	0.51	1.22	0.96	1.19
Outer rhizosphere ...	—	1.36	1.44	1.18	0.94	0.83	—	—	1.63	1.49	1.15	0.86	1.17	1.23	1.37	0.61	1.17
Inner rhizosphere ...	—	—	0.88	0.33	0.65	1.06	—	—	0.68	0.72	3.64	1.64	1.65	1.55	—	3.6	1.48

The effect of the living roots in increasing the bacterial population in the outer rhizosphere as compared with the soil did not appear to be very marked. It was greater at the beginning of the season in both plots and on the average was slightly more pronounced in the steamed plot as shown in Table III.

TABLE III
RATIOS OF NUMBER OF BACTERIA IN THE OUTER RHIZOSPHERE TO NUMBER IN THE SOIL IN STEAMED AND UNSTEAMED PLOTS

		April		May		June		July		Aug.		Sept.		Oct.		Nov.		Mean
Steamed ...	...	2.08	2.44	0.88	0.86	4.3	—	—	3.09	—	1.41	—	1.44	1.04	0.55	1.46	1.77	
Unsteamed	...	2.49	2.3	0.38	1.16	—	2.23	—	2.0	—	1.62	0.7	—	1.24	1.47	0.71	1.48	

Steaming the soil slightly decreased the numbers of bacteria found in the soil and outer rhizosphere, but the larger numbers in the inner rhizosphere in steamed soil compared with those in the inner rhizosphere in unsteamed soil at the beginning of the season, indicates that the roots of the plants in the steamed soil exert the more beneficial effect on the bacterial population. It seems that this increase in the bacterial population is confined to the root surface and does not extend far into the soil surrounding the roots. The increase in bacterial numbers on roots from unsteamed soil during the later part of the season is almost certainly due to the greater preponderance of roots showing lesions or decay under these conditions.

The numbers of fungi isolated from the soil showed a marked decrease due to steaming. Towards the end of the year numbers in the steamed soil rose, while in the unsteamed soil they fell slightly, so that the ratio of numbers in unsteamed soil to those in steamed soil dropped. (See Table IV.)

Although the unsteamed soil contained the larger number of fungi this difference between the steamed and unsteamed plots was not reflected in the outer rhizosphere, where the variation in numbers isolated from the two different plots was relatively small. This appears to be due to the lack of a pronounced rhizosphere effect in the unsteamed soil. It was not until July that fungi in this rhizosphere showed an increase when compared with numbers from the soil, whereas in the steamed plot the rhizosphere fungi were markedly greater in number compared with soil fungi throughout the growing season. (See Table VI.)

Fungi from the root surface were usually isolated in considerably greater numbers from roots in unsteamed soil, although there was wide variation during the season.

TABLE IV
RATIO OF NUMBER OF FUNGI IN THE UNSTEAMED PLOT TO NUMBER IN THE STEAMED PLOT

	April		May		June		July		Aug.		Sept.		Oct.		Nov.		M'n
Soil	5.25	2.37	9.75	3.36	4.07	11.17	1.45	1.67	—	4.97	1.84	2.2	2.35	1.52	1.63	1.99	3.7
Outer rhizosphere	—	3.64	1.32	0.82	0.56	0.97	1.22	1.77	1.33	0.93	0.56	1.15	1.73	3.45	1.67	0.64	1.45
Inner rhizosphere	—	—	14.56	0.92	3.99	7.25	1.36	8.97	3.43	4.53	11.42	0.25	3.62	1.78	—	2.57	4.97

The range and the mean value of the actual numbers of fungi counted from the three different sources in the two plots are shown below (Table V).

TABLE V
NUMBER OF FUNGI ISOLATED

	Number of Colonies per gm. Dry Soil				Number of Colonies per sq. cm. Root Surface	
	Soil		Outer Rhizosphere		Inner Rhizosphere	
	Steamed	Unsteamed	Steamed	Unsteamed	Steamed	Unsteamed
Range... ..	32,060-97,600	69,874-444,040	71,852-229,311	120,750-264,292	193-5,578	178-5,040
Mean	52,363	203,439	151,362	181,989	1,309	4,247

As noted above, the rhizosphere effect in the unsteamed soil was not apparent until the middle of the season when the roots in this plot often showed extensive lesions accompanied by shedding of the cortical tissues, whereas the rhizosphere in the steamed plot had a definite and continuous beneficial effect on the fungal population. See as in Table VI.

TABLE VI
RATIOS OF NUMBER OF FUNGI IN THE OUTER RHIZOSPHERE TO NUMBER IN THE SOIL IN
STEAMED AND UNSTEAMED PLOTS

	April	May		June		July		Aug.		Sept.		Oct.		Nov.		Mean
Steamed	1.54	2.73	2.24	3.43	4.37	2.79	1.29	—	1.89	2.67	3.74	1.64	0.69	2.31	2.02	2.38
Unsteamed	2.36	0.37	0.55	0.6	0.38	2.85	1.88	—	1.77	1.01	2.62	1.63	1.86	3.05	0.76	1.55

It seems that steaming the soil is most effective in destroying the fungal population in the soil, its effect on the general level of bacterial activity being less marked. It is probable that many of the bacteria present in the soil are not killed by steaming and during the period between steaming and the house being planted the bacterial population has time to increase to the normal level. Fungi, however, are more susceptible and reinfection by airborne spores and increased growth when the temperature rises in the spring are not sufficient to raise the level of the fungal population in the steamed soil to that in the unsteamed soil. Although the fungal population increases in the proximity of living roots in the steamed soil it still does not equal the numbers in the outer rhizosphere in unsteamed soil. On the root surface there is an even greater difference, the numbers from unsteamed soil being generally considerably larger than those from roots in steamed soil.

TABLE VII
DISTRIBUTION OF THE MOST FREQUENTLY ISOLATED FUNGI

	Soil		Outer Rhizosphere		Inner Rhizosphere	
	Steamed	Unsteamed	Steamed	Unsteamed	Steamed	Unsteamed
<i>Penicillium</i> spp. } <i>Mucor</i> spp. } <i>Trichoderma viride</i> } <i>Myrothecium roridum</i> } <i>Chaetomium</i> spp. } K } <i>Fusarium</i> spp. } <i>Botrytis cinerea</i> }	...	...	+	+	+	+
<i>Volutella ciliata</i> ...	...	...	+	+	+	+
<i>Phytophthora</i> spp. ...	...	...	+	+	+	+
<i>Pythium</i> sp. ...	...	...	+	+	+	+
<i>Mortierella</i> sp. ...	...	...	+	+	+	+
<i>Rhizopus</i> sp. ...	...	...	+	+	+	+
<i>Colletotrichum atramentarium</i> ...	...	...	+	+	+	+
Total Number Genera Isolated	22	23	22	17	20	13

Not all the species of fungi isolated could be identified, and although cultures were kept for comparison of the sporangia forms, other fungi which produced only sterile mycelia were discarded. The genera *Penicillium* and *Mucor* were common but were not generally identified as to species. The grey sterile fungus K. previously reported from root lesions was occasionally isolated, and isolations

were also made of a fungus which appeared similar in mycelial characters but produced pycnidia. This pycnidial form was also isolated this season from lesions on roots together with the sterile form, and it seems probable that it may be a fruiting strain of the fungus K; for convenience these two fungi have been listed together. *Trichoderma viride* and *Myrothecium roridum* were fairly common and species of *Chaetomium*, of which *C. cochloides* was frequent, were also found. *Fusarium* spp. occurred often, but usually only a few forms produced macrospores. Species of *Volutella* were isolated less frequently and were more restricted in habitat. Of the 40 genera isolated in culture, 17 occurred only once or from only one habitat. The occurrence of the more important fungi is shown in Table VII.

The apparent increase in the numbers of genera isolated from the rhizospheres in steamed soil compared with the similar habitat in unsteamed soil, seems to be due to the larger number of single isolations made from this source. Several unidentified fungi, and also *Petriella asymmetrica* and *Gelasinospora* spp. were isolated from the rhizosphere in steamed soil, and it seems probable that these fungi only occur where competition of other micro-organisms has been reduced by steaming.

The most commonly isolated fungi from all three habitats were species of *Penicillium* and *Mucor* and the occurrence of these and the other most frequently isolated fungi is shown in Table VIII.

TABLE VIII
OCCURRENCE OF FUNGI:

A.—NUMBER OF SAMPLES FROM WHICH THE FUNGUS WAS ISOLATED DURING THE SEASON
B.—AVERAGE NUMBER OF THE SPECIES ISOLATED AS A PERCENTAGE OF TOTAL POPULATION

			Soil		Outer Rhizosphere		Inner Rhizosphere	
			Steamed	Unsteamed	Steamed	Unsteamed	Steamed	Unsteamed
Total number of samples	...		15	15	15	15	14	13
<i>Penicillium</i> spp.	...	A	15	15	15	15	14	12
		B	31.15	35.7	18.38	18.97	14.11	27.55
<i>Mucor</i> spp.	...	A	15	13	15	15	11	9
		B	30.8	11.5	35.71	18.67	8.41	9.33
<i>M. roridum</i>	...	A	10	13	5	13	5	7
		B	9.3	16.12	1.69	3.53	0.58	3.64
<i>T. viride</i>	...	A	7	7	15	12	8	3
		B	2.2	1.48	4.92	2.93	1.03	1.89
<i>Fusarium</i> spp.	...	A	2	10	10	5	5	6
		B	1.9	4.98	4.85	1.37	10.00	9.33
<i>Volutella Ciliata</i>	...	A	4	3	6	1	7	0
		B	1.3	0.63	2.46	0.17	3.75	—
K	...	A	11	10	6	8	2	3
		B	6.5	2.75	1.76	1.14	0.25	1.45
<i>Chaetomium</i> spp.	...	A	1	3	1	3	4	4
		B	0.51	0.424	0.070	0.17	0.51	1.02
<i>Colletotrichum atramentarium</i>	A		1	1	2	0	9	10
	B		0.173	0.212	0.14	0	18.64	16.32

Penicillium spp. and *Mucor* spp. occurred regularly from all habitats and in comparatively large numbers throughout the season. Numbers of *Penicillium* tended to be higher in samples from unsteamed plots while *Mucor* spp. were more numerous from the steamed plot. These fungi were less frequent from the inner rhizosphere in both plots.

M. roridum appeared most commonly in unsteamed soil, and numbers isolated from both rhizospheres were less than from the corresponding soils. This decrease is more marked in the steamed than in the unsteamed rhizosphere. The more frequent isolation of this fungi from the unsteamed plot is also apparent when comparing the distribution throughout the season as *M. roridum* appeared earlier in all three habitats in the unsteamed plot. The numbers isolated tended to increase in soil towards the end of the season, but numbers isolated from the rhizosphere were very varied.

T. viride was isolated most frequently from the outer rhizosphere of plants in the steamed plot, and was found in more samples from the inner rhizosphere than from the soil. In the unsteamed plot, however, although it was again most frequent in the outer rhizosphere it occurred in more samples from the soil than from the root surface. The actual numbers of this fungus which were isolated were at variance with the distribution indicated by the number of records of its appearance. Thus in the steamed plot the average percentage isolation was lowest in the inner rhizosphere. In

the unsteamed plot numbers isolated were on the average highest in the outer rhizosphere while the average numbers isolated from the inner rhizosphere were higher than those from the soil, although it was only occasionally isolated from this source. With freely sporing fungi such as *Trichoderma* the number of colonies recorded from a dilution plate does not necessarily give a reliable picture of its activity in the soil, and it seems probable that this fungi is generally more active in the rhizosphere of plants in steamed soil.

Fusarium spp. showed a rather similar trend in distribution, occurring more frequently in the rhizosphere in the steamed plot. In the soil, however, they were isolated only rarely from the steamed plot, while in unsteamed soil they occurred regularly at the end of the season. *Volutella ciliata* showed a similar marked preference for the rhizosphere of plants in steamed soil. It was only isolated once from the rhizosphere in the unsteamed plot and rarely from unsteamed soil. This fungus tended to occur earlier in the season than *Fusarium* spp. and was not isolated at all at the end of the year.

The grey fungus K was first isolated from steamed soil in April and was most common from that source. It did not appear in unsteamed soil until June and was not isolated from the outer rhizospheres until August, after which it occurred fairly regularly. Its isolation from the root surface was rare, but the two earliest records from the unsteamed plot were in May and June, while from the steamed plots the two records were in August and November. In both plots it was less common in the rhizosphere than in the soil. Species of *Chaetomium* were comparatively rare from all three habitats, but tended to be most frequent from the unsteamed inner rhizosphere. In the steamed plot *Chaetomium* was recorded more frequently from the inner rhizosphere than from the soil.

Colletotrichum atramentarium is the only species isolated which shows a really marked preference for the root surface habitat. It was isolated at the beginning of June from the inner rhizosphere of plants in unsteamed soil, and at the end of June from roots in the steamed plot, and was one of the dominant species from the inner rhizosphere in both plots. Its rare occurrence in the soil and outer rhizosphere seems to indicate that this fungus cannot spread very freely through the soil and probably survives only in decaying roots.

A comparison of the fungi found on the root surface with those isolated from internal tissues of the root showed some correlations. *Colletotrichum atramentarium* was slightly more frequent from roots in steamed soil but was not isolated from this source until July, whereas it was isolated from roots in unsteamed soil as early as April. The larger numbers of this fungus isolated from the roots in steamed soil in the latter half of the season is probably due to fewer saprophytic fungi invading the diseased roots. *Volutella ciliata* was more common from roots in steamed soil but it was also isolated occasionally from those in unsteamed soil, although it was not found in the root surface in this plot. The fungus K was more frequent from roots in the unsteamed soil and in both plots was isolated earlier from root tissues than from the root surface. *Fusarium* spp. were more numerous from unsteamed soil and again in both plots were isolated from root tissues before being recorded from the root surface.

It would be expected that fungi capable of actively parasitising tomato roots would be favoured by the root surface habitat. On this supposition it seems that *C. atramentarium* and *Fusarium* spp. are the two fungi most likely to invade the roots, while in steamed soil *V. ciliata* might do so. *Chaetomium* spp. are also rather more frequent on the root surface and may occasionally invade the roots. The fungus K, however, does not seem to be favoured by the rhizosphere habitat and may be present in the diseased root tissue only as a secondary saprophyte.

If infection of the living root always took place directly from the soil adhering to the root surface it would be expected that the invading fungus could be isolated from the root surface before being found in the root tissue. But this does not seem to occur. It is, however, possible that primary root infection early in the season is more likely to occur when a living root grows in contact with a piece of organic debris harbouring a potential pathogen. This would account for the early appearance of *C. atramentarium* and K in the roots, especially in unsteamed soil, as both these fungi have been found to overwinter in root debris which appears to persist longer in the unsteamed plot.

2. DIDYMELLA STEM ROT

By P. H. WILLIAMS and JUDITH HACK

(1) Observations on the Station Nursery

A slight outbreak of *Didymella* Stem Rot occurred on the nursery in 1951 and enabled some observations to be made on the spread of the disease and the effect of straw mulches.

The disease was first found on May 31st in house 10. More plants died or were found to be infected throughout the remainder of the season. The distribution of the diseased plants was as follows:—

House 8.	Two plants with lesions above soil level. One fruit on the third truss.
House 9.	One fruit on the fourth truss.
House 10.	Six plants, all infected at soil level.
House 11.	Twelve plants, six infected at soil level and six slightly above.
House 12.	One plant infected at soil level.
Rose House.	Four plants infected at soil level.
Parasite House.	Two plants infected at soil level.

All the evidence suggested that the infection was airborne. Plates of Dox agar were exposed in various positions at the west end of the nursery and the presence of *Didymella* spores in the air confirmed.

So far as spread of the disease after initial infection is concerned, only in house 11 did there seem to be any evidence that it had taken place. In this house all the infected plants except one occurred in rows 36 to 42 on the east side. The first infected plant was found on June 25th, while most of the others were not found until nearly a month later. The disease may, therefore, have been spread during watering from the first infected plant.

It is remarkable, however, how localised the disease has always been on this nursery. Evidently some factor either biological or cultural limits the spread of the disease.

It has been reported in the Annual Report for 1949 that *D. lycopersici* will grow and fruit on wheat straw and it is possible therefore that straw mulches may be a factor in the establishment and spread of the disease. If this were the case, it might be expected that the two side borders in the Rose House which were mulched with straw would be more heavily infected than the unmulched centre bed. In fact, however, the four infected plants occurred in the centre bed. Again in houses 11 and 12, which were mulched, the disease remained localised.

Samples of straw near infected plants were examined for pycnidia of *Didymella* but none were found. It seems probable that the fungus was unable to colonise the straw when in competition with other organisms and that straw mulches are not of great importance in spreading the disease.

(2) Growth of *D. lycopersici* in Tomato Stems

Cutting out small lesions or painting them with fungicidal solutions have been recommended, but in our trials the fungus has invariably grown out again above or below the treated section. This year some observations have been made on the distance beyond the visible lesion to which the fungus may extend in the interior of the stem.

Isolations were made at 2-in. intervals from the vascular and cortical tissue of stems from the diseased plants found on the nursery. Cultures of *Didymella* so obtained were checked by inoculation into tomato stems.

It was found that the fungus was present 14 ins. above a lesion $3\frac{1}{2}$ ins. long. With a lesion $\frac{1}{2}$ in. long affecting only one side of the stem, the fungus was detected 6 ins. higher up. In most cases, the fungus was isolated 4 to 7 ins. above the upper edge of the lesion.

These results explain the failure of our previous attempts at cutting out or treating lesions and suggest that when infected plants are removed, the stem should be cut through at least 2 ft. above the lesion and that part of the stem destroyed. If only the visibly infected part of the stem is destroyed, there is a chance that a considerable length of stem containing the fungus will be placed on the rubbish heap.

(3) Depth of Survival in the Soil

In the Annual Report for 1950, experiments were described in which spores were buried at various depths in the soil. This experiment was repeated this year, using the procedure already described.

Nine weeks after inoculation, none of the plants were infected in the pots where the spores had been buried 4 ins. deep. One plant was infected in the 2-in. series and all five in the surface inoculated pots.

This result confirms that of the first experiment carried out last year. As previously suggested, the infection of the plants from buried spores in the second of the 1950 experiments may have been due to lower temperatures which favoured the growth of *Didymella* in the soil.

(4) The effect of Temperature on growth of *Didymella* in Soil

Further experiments have confirmed the results previously reported. When soil cultures were incubated on the laboratory bench for five weeks and then placed at temperatures of 80° F., 61° F.,

and 40° F. there was again a very striking fall in the numbers of colonies in plates poured from these placed at 80° F.

(5) Methods for isolating *Didymella* from Soil

It is difficult to estimate the amount of *Didymella* in unsterilized soil because of competition from other organisms in the plates. Some success has been obtained in eliminating bacteria by adding rose bengal to the medium but this does not affect fungi. Considerable attention has been paid to this problem. The reaction of *Penicillium* sp. from soil has been compared with that of *Didymella* and for convenience spores of both fungi have been mainly used.

(a) VARIOUS FUNGICIDAL SUBSTANCES

Mrs. Sheard noticed that spores treated with 10 per cent. copper sulphate for one hour would germinate if transferred to tomato juice. It has subsequently been found that a small proportion will germinate after 48 hours in 10 per cent. copper sulphate if placed in tomato juice. It was hoped that the addition of tomato juice to copper sulphate solutions might protect *Didymella* against the copper sulphate while not protecting other organisms. It was found, however, that the effect of tomato juice was non-specific and that it also protected *Trichoderma viride* and *Penicillium* spp. against copper sulphate.

Other compounds tested included dimethylchlorfumarate (reported to be very fungicidal to some species of *Penicillium*²), 2 per cent. boric acid, saturated salicylanilide and sodium propionate, but none of them showed any selective action.

(b) FUMIGATION

In the early work on soil sterilization, toluene was used as a soil fumigant. Spores of *Didymella* and *Penicillium* sp. were exposed in a closed vessel to air saturated with toluene vapour for varying periods. The injurious effects on both were similar.

(c) HEAT

The possibility of eliminating unwanted organisms by heating the soil was also investigated. The thermal death point of *Didymella* mycelium was found to be about 111° F. (10 minute exposure) and of spores about 115° F. This is slightly lower than the thermal death point of most fungi and bacteria and therefore this method is obviously unsuitable.

(d) PHYSICAL METHODS

So far as spores are concerned certain physical methods based on the characters of the spore coat might be used to separate *Didymella* and some other fungi such as *Penicillium*. The spores of the former are classified as "slime spores" since they are held together by mucus and tend to stick together. They are easily wetted. Those of *Penicillium* on the other hand have waxy coats, separate easily, and are hard to wet.

An aqueous suspension of a mixture of spores of *Didymella* and *Penicillium* was shaken up with paraffin. It was hoped that when the two liquids separated the *Penicillium* spores would pass into the oil layer and the *Didymella* into the water. It was found, however, that some of the *Penicillium* spores remained in the water layer.

Burges¹ has shown that "dry spores" like those of *Penicillium* are not washed so far into sandy soils as are "slime spores." The possibility of using this fact to separate *Didymella* from other fungi has been investigated.

The method consisted in watering suspensions of spores and mycelial fragments derived from pure cultures on agar or soil on to the surface of a column of wet sand contained in a narrow glass tube. The numbers and proportions emerging at the bottom of the cylinder were compared with those in the original suspension.

It was found that while in general more *Didymella* emerged than *Penicillium*, the results depended on a number of factors which included the size of the sand particles, the length of the sand column, and the amount of water in the sand. In spite of standardising these factors it still proved difficult to obtain consistent results.

(e) METHODS OF CULTIVATION

It was found that separation of *Didymella* and *Penicillium* could be effected when green tomatoes were inoculated with a mixed spore suspension of the two fungi either in water or soil suspension, since the *Didymella* grew more rapidly. Soil organisms present in the soil suspension did not affect the growth of *Didymella* except in one experiment in which a good deal of *Botrytis* was present and outgrew the *Didymella*. This method has obvious possibilities for demonstrating the presence of *Didymella* in soil, but it would be difficult to adapt it to quantitative work because 100 per cent. infection did not take place when only a small number of spores were present in the suspension.

Comparison of the relative numbers of *Didymella* and bacterial colonies developing on plates of Dox agar and of a medium suggested by Sleeth³ for the isolation of *Pythium* spp. showed that the latter, while not reducing the numbers of *Didymella* colonies, markedly reduced those of bacteria. The growth of Phycomycetes such as *Mucor* spp. was slowed up. The addition of 0.0067 per cent. rose bengal to the Sleeth medium was found to eliminate actinomycetes.

In further experiments it was found that reduction of the sugar content of the rose bengal-Sleeth medium caused a large increase in the number of fungi isolated from unsterilized soil. When *Didymella* spores were added to unsterilized soil, it was found that within limits the number of colonies appearing on plates was also inversely proportioned to the sugar content.

In the course of these tests, more *Didymella* colonies appeared on the plates in one experiment when the plates were incubated at room temperature than in a subsequent one in which the plates were incubated at 70° F. This led to an investigation of the effect of temperature on the number of *Didymella* colonies developing on plates poured from soil inoculated with spores of that fungus. Equal amounts of suspensions of sterilized and unsterilized soil were inoculated with equal numbers of spores and plates poured from them. When incubated at 63° F. the plates from the unsterilized soil contained as many *Didymella* colonies as those from the sterilized soil. Incubated at 70° F., the numbers from unsterilized soil were considerably less than those from sterilized soil. Low temperatures, therefore, favour the development of *Didymella* in the plates by slowing up the growth of competing fungi, the *Didymella* itself not being so severely affected by the low temperatures.

The use of this medium combined with incubation of the plates at low temperatures promises to be of considerable value in investigating the growth and survival of *Didymella* in glasshouse soils. It is at times difficult to identify the *Didymella* colonies if the plate is crowded but this may be overcome by inoculating green tomatoes with doubtful colonies.

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3. FUNGICIDES

(a) Laboratory Investigations

By W. H. READ and R. J. SMITH

The investigations of the fungitoxic and phytotoxic activities of quinonoid and related compounds have been continued. The related compounds have been examined in an attempt to find substances less phytotoxic than quinones but highly fungitoxic, possibly through their conversion by the fungus or other agency to the corresponding quinone.

The following are some of the points of interest which have arisen.

Oximation of *p*-quinones appears to reduce considerably their fungitoxic and phytotoxic activities. Acetylation of the oxime has little effect on the molar activity.

The presence of chlorine in the 5 : 8- positions of 1 : 4-naphthaquinone enhanced fungitoxicity slightly and considerably reduced phytotoxicity and the 6-nitro-2 : 3-dichloro-1 : 4-naphthaquinone mentioned in the last report is somewhat less phytotoxic to tomato plants than is 2 : 3 dichloro-1 : 4-naphthaquinone.

1 : 2-Naphthaquinone possesses only half the potency of 1 : 4-naphthaquinone and 3-nitro-1 : 2-naphthaquinone is still less fungitoxic.

The chlorohydroquinones are much more toxic than hydroquinone to spores of *Fusarium culmorum* without being more phytotoxic, whereas two nitrohydroquinones proved somewhat less fungitoxic, and much more phytotoxic than the corresponding chloro derivatives.

The diacetyl derivative of 2 : 5-dichlorohydroquinone, while far less toxic to *F. culmorum* than the parent compound, is only slightly inferior to the latter (at pH5) against *Alternaria circinans* and *Didymella lycopersici*. It is suggested that this degree of specificity may be due to a greater ability of the spores of *A. circinans* and *D. lycopersici* to hydrolyse the ester.

The diacetyl derivative of 2 : 3 : 5 : 6-tetrachlorohydroquinone, however, is much less toxic to *A. circinans* and *D. lycopersici* than 2 : 3 : 5 : 6-tetrachlorohydroquinone and the above 2 : 5-dichlorohydroquinone diacetate.

The reason for the relatively non-toxic nature of tetrachlorohydroquinone diacetate may be its

less facile hydrolysis by the spores concerned, owing to "steric hindrance." The lack of toxicity of the diacetate of higher chlorine content would tend to support the "hydrolysis" theory of toxic action, since one might expect it to be not greatly inferior to the dichloro-compound in penetrating a spore wall.

The above chlorohydroquinones and diacetates were less phytotoxic, to tomato plants, than the corresponding quinones, and 2 : 5-dichlorohydroquinone diacetate was less phytotoxic than 2 : 5-dichlorohydroquinone.

It is also suggested that the toxicity of certain 1 : 4-diamino benzenes and naphthalenes may be due to their conversion to the corresponding quinonoid compounds by fungus spores. For example, 2-iodo-1 : 4-diaminonaphthalene is about half as toxic as 2-iodo-1 : 4-naphthaquinone to spores of *Fusarium culmorum* and is also very toxic to spores of *A. circinans* and *D. lycopersici*. 4-Amino-3-bromo-2-nitro-1-naphthol, one of the most active of the compounds tested (at pH5) against *F. culmorum*, *A. circinans* and *D. lycopersici*, was somewhat phytotoxic. The replacement of bromine by iodine considerably reduced fungitoxicity.

(b) Preliminary Investigations of Fungicides for the Control of Cucumber Mildew

By W. H. READ

Introduction

Whereas copper-petroleum emulsion sprays give effective control of cucumber mildew, *Erysiphe cichoracearum*, they are expensive, particularly so now that alternative control measures for the control of Red Spider have largely replaced the use of petroleum emulsion sprays for this purpose. Many new fungicides have been introduced since investigations on the control of this disease showed the value of copper oxychloride-petroleum emulsions and, in view of these considerations an investigation of the potential value against cucumber mildew of some recently introduced fungicides has been commenced.

Some of the materials tried are stated to effectively control powdery mildew of cucumbers in America when applied at intervals of five to seven days, but fungicidal sprays requiring very frequent applications are regarded as undesirable in this country.

Eradicative fungicidal action to destroy the actively growing fungus is desirable in glasshouse crop protection in addition to protective fungicidal action whereby spores of the fungus are destroyed by the deposit of fungicide on the leaves before they germinate and infect the plants.

Method

In these preliminary trials, made in order to indicate the most promising fungicides for future large-scale trials, both the above properties were broadly assessed by applying the materials to cucumber plants having their lower leaves visibly attacked by the fungus. To obtain some quantitative record of the fungicidal values of the substances examined, the eradication action was assayed by estimating the percentage area of each leaf visibly attacked by the living fungus before and 18 days after spraying. Protective action was assayed after the same interval estimating the percentage area visibly attacked by mildew of leaves which at the time of spraying were three or more inches in length and free from visible mildew. The very limited glasshouse accommodation available for these experiments, in which large plants in pots were used, made it necessary to conduct a series of trials over a long period. The plants were as uniform in size as possible throughout and cultural conditions were kept as uniform as conditions permitted. Plants sprayed with a standard copper oxychloride-petroleum emulsion mixture and unsprayed control plants were included in each trial. The presence of unsprayed, infected plants provided a continuous natural source of infection for the sprayed plants.

Whilst the conditions in these tests were similar to those which are experienced in practice, the level of potential infection being higher than in normal cucumber houses, they do not permit precise distinction between eradication and protective action. Furthermore, the estimation of the percentage area of cucumber leaves visibly infected with *Erysiphe* is subject to large errors and the figures recorded in Table I must not be regarded as precise measures of relative fungicidal efficiencies.

Materials

The fungicidal compounds and preparations tested are listed. Unless stated otherwise, the

Date of Test	Treatment	Mean percentage Leaf Area with Living Mildew on Leaves visibly infected when Sprayed		Mean percentage Leaf Area Mildewed on Leaves not visibly infected when Sprayed
		When Sprayed	After 18 Days	
20/4	Standard copper oxychloride-petroleum emulsion mixture, 0.06% Cu., 0.35% Oil	20	6	2.5
	Thiram., 0.1%	17	33	20
	" 0.05%	23	28	17
	" 0.025%	12	38	31
	Control	15	> 40	37
10/5	Standard copper-petroleum	18	3	4
	Ziram., 0.4%	16	> 40	13
	" 0.2%	12	> 40	27
	" 0.1%	18	> 40	20
	Nabam., 0.2%	15	Not recorded owing to damage to plants	
	" 0.1%	11		
	Zineb., 0.2%	10	20	5
	" 0.1%	15	15	17
	Control	8	> 40	> 40
13/6	Standard copper-petroleum	17	3.5	5.5
	Z.A.C., 0.2%	19	> 40	> 40
	" 0.1%	14	> 40	> 40
	Copper dimethyldithiocarbamate, 0.2% ...	14	> 40	> 40
	" " 0.1%	14	> 40	> 40
	" " 0.05%	15	> 40	33
	Sodium pentamethylene dithiocarbamate, 0.2%	18	> 40	> 40
	Ditto, 0.1%	16	> 40	> 40
	Ditto, 0.05%	8	> 40	> 40
9/8	Standard copper-petroleum	8	3	1.5
	341C., 0.5%	}	Not recorded owing to damage to plants	
	" 0.25%			
	" 0.12%			
	341SC., 0.5%			
	" 0.25%			
	" 0.12%			
	Control	12	> 40	> 40
9/9	Standard copper-petroleum	16	3	1
	2 : 3-dichloro-1 : 4-naphthaquinone, 0.1% ...	17	1	—
	" " 0.4%	22	1	1
	" " 0.025%	16	9	1
	Tetrachlorobenzoquinone, 0.1%	15	20	5
	" 0.05%	16	36	3
	" 0.025%	18	37	3
	Control	15	> 40	37
	341C without lime, 0.1%	}	Not recorded owing to damage to plants	
	341SC without lime, 0.1%			

compounds were commercially pure products and were applied as suspensions or solutions in 0.1 per cent. Lissapol N. The same concentration of this wetting agent was used with the sprays prepared by diluting certain proprietary products but was omitted from the standard copper-petroleum spray.

(a) Standard copper-petroleum mixture—an admixture of a proprietary copper oxychloride suspension and a proprietary glasshouse-type petroleum emulsion. The spray contained 0.06 per cent. Cu and 0.35 per cent. petroleum.

(b) Thiram—tetramethyl thiuramdisulphide.

(c) Ziram—zinc dimethyldithiocarbamate.

(d) Nabam—sodium ethylene bisdithiocarbamate.

(e) Zineb—zinc ethylene bisdithiocarbamate.

(f) Copper dimethyldithiocarbamate.

(h) Goodrite Z.A.C.—stated to be a ziram-cyclohexylamine complex.

(i) 341C—stated to have the following composition:—

2-heptadecyl glyoxalidine acetate	...	...	32	per cent.
2-pentadecyl glyoxalidine acetate	...	...	16	„ „
2-heptadecenyl glyoxalidine acetate	...	...	2	„ „
<i>iso</i> propanol	...	...	50	„ „

Sprays were prepared by adding hydrated lime to the diluted 341C in the proportion of one part lime to five parts 341C and thoroughly stirring. One test was made in which no lime was added.

(j) 341SC—stated to consist of a 34 per cent. wt/wt solution of 2-heptadecyl glyoxalidine acetate in *iso* propanol. Sprays were prepared with lime as for 341C and one phytotoxicity test was made without the addition of lime.

(k) 2: 3-dichloro-1: 4-naphthaquinone. (This is the active material in the American product 'Phygon XL'.)

(l) 2: 3: 5: 6-tetrachloro-1: 4-benzoquinone. (This is the active material in 'Spergon' preparations.)

Discussion

The most outstanding fungicide tested in the trials was 2:3-dichloro-1:4-naphthaquinone, but further trials are necessary to determine its phytotoxicity to cucumbers. The 0.1 per cent. concentration caused obvious damage to leaves which were expanding at the time of application and the 0.05 per cent. concentration appeared to cause slight injury under the test conditions. Formulations of dichloronaphthaquinone containing magnesium sulphate are said to be less injurious to plants and trials with such formulations are envisaged. Zinc ethylene bisdithiocarbamate was the only dithiocarbamate to merit further trials.

The glyoxalidine preparations 341C and 341SC were highly injurious to cucumbers. Neither zineb or dichloronaphthaquinone are freely available at present in this country and relative costs of these and copper-petroleum sprays cannot be quoted.

Although the initial infection of the plants and post-spraying inoculation potentials were much higher than they would normally be in commercial houses the coverage of the plants by the sprays was greatly superior to that which can be obtained in commercial practice.

We are indebted to Dr. A. H. M. Kirby, Messrs. Robinson Bros. Ltd., and Messrs. Honeywill and Stein Ltd., for supplies of a number of the compounds.

5. VIRUS DISEASES

By R. HOWLES

(a) Heat Treatment of Tomato Seeds

It has been found previously that heat treatment of tomato seed in a normally humid atmosphere at 135° F. for eight days had little effect on the seed itself and destroyed the small amount of virus present. This year an attempt has been made to determine for this treatment the time of inactivation of half the virus content.

Fifty grams of completely separated L.M.R. No. 1 tomato seed (freed from small seed) taken from highly infected plants was mixed thoroughly. The seed was shown to contain tobacco mosaic virus only. Out of this mixture nine lots each weighing 2 grams were weighed and were given various heat treatments in normal atmosphere.

The effect of Heat Treatment on the Seed itself

Table I records the data concerning the effect of heat treatment on the seed itself.

The relation between average seedling weight as a fraction of normal weight and duration of the heat treatment in the case of each temperature is given in Fig. 1.

There was little effect on the number of seeds which germinated, and all the seedlings were normal. The heat treatments used increased the average weight of seedling. Relatively short periods of heat treatment had a considerable effect. Thus seed treated for four hours at 150° F. gave seedlings 50 per cent. heavier than those from untreated seed.

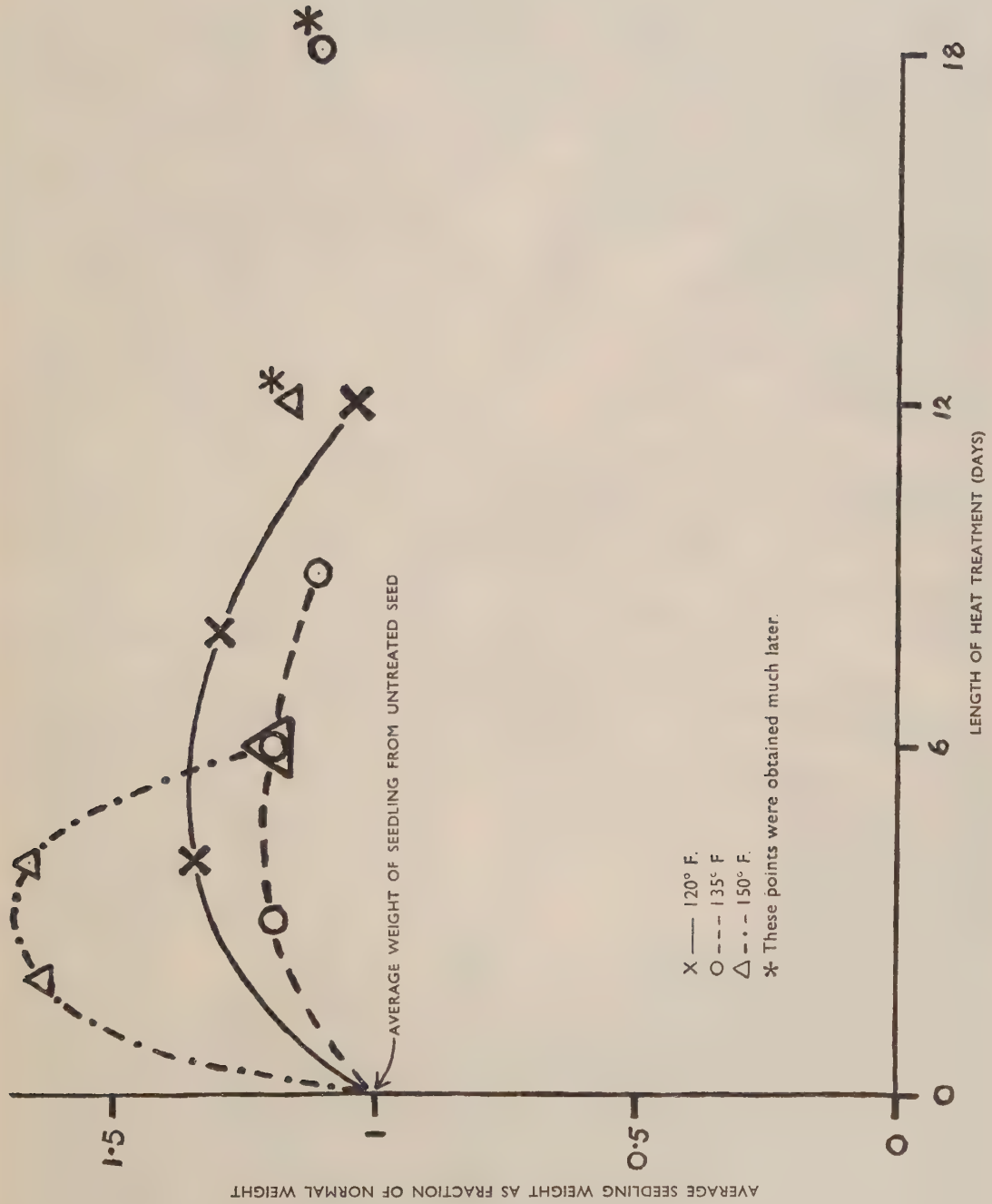


Fig. 1

The relation between average tomato seedling weight as fraction of normal weight and duration of heat treatment in normal atmosphere.

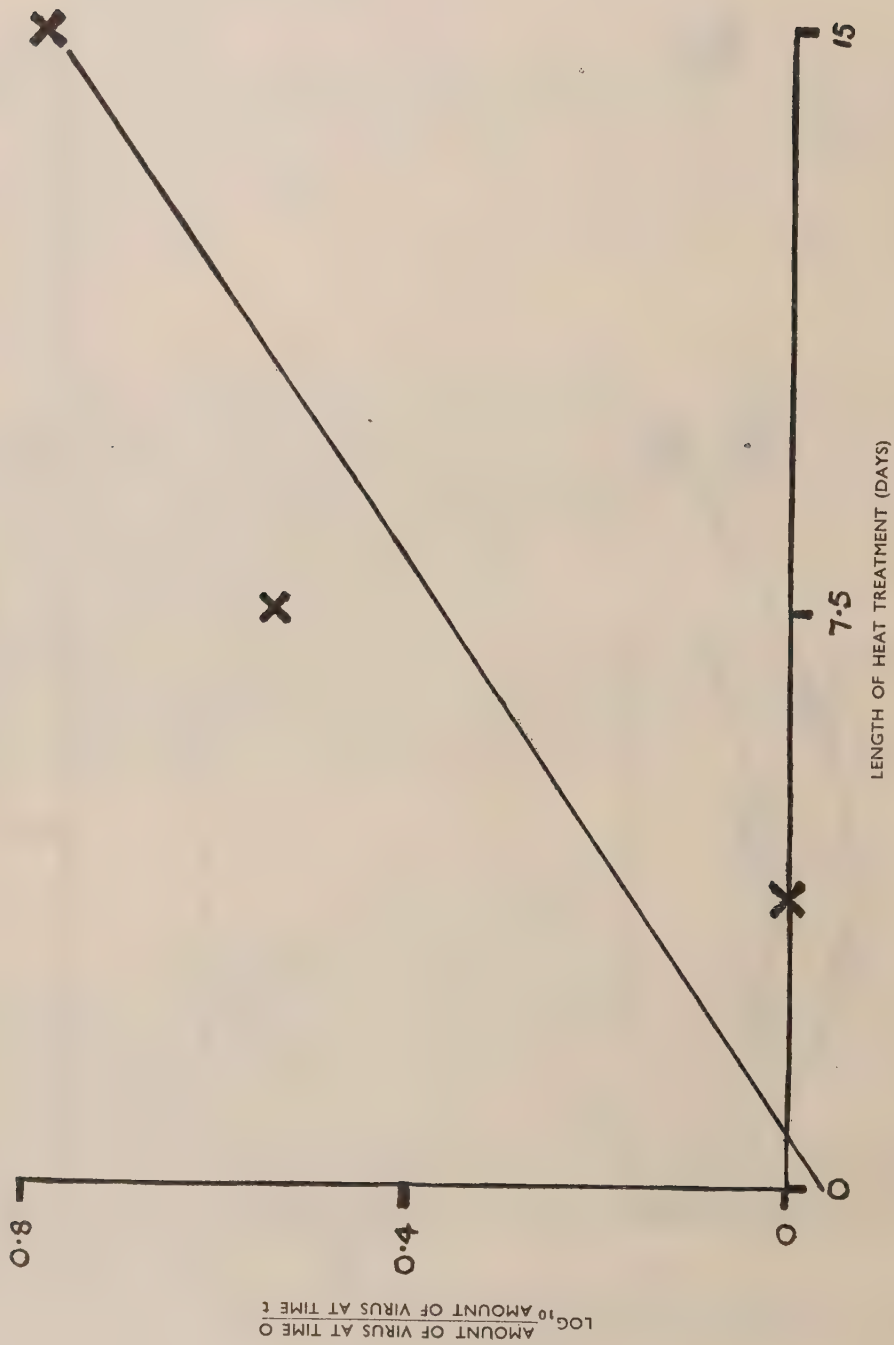


Fig. 2

The effect of length of heat treatment in normal atmosphere at 142.5° F. on the virus content of tobacco mosaic virus infected tomato seed.



Fig. 3

Chrysanthemum moraei. Variety *Favourite*. Double-flowered.



Fig. 4

Chrysanthemum mosaic, Variety Friendly Rival. Infected bloom left. Control right.



Fig. 5
Chrysanthemum mosaic. Variety: Valiant. Infected blooms right. Control left.



Fig. 6

Chrysanthemum morifolium, Variegated Shirley Line Red. Infected bloom (left), Control (right).

TABLE I

THE EFFECT OF HEATING VIRUS-INFECTED TOMATO SEED IN NORMAL ATMOSPHERE ON THE SEED ITSELF

Treatment		Number of Seeds germinating out of of 45, 17 Days after Sowing	Appearance of Seedlings	Average Weight of Seedling (Grams)
Temperature ° F.	Duration (Days)			
120	4	37	Normal	0.084
120	8	42	"	0.080
120	12	41	"	0.065
—	—	40	—	0.062
135	3	39	Normal	0.081
135	6	40	"	0.082
135	9	35	"	0.076
—	—	38	—	0.068
150	2	42	Normal	0.113
150	4	42	"	0.115
150	6	44	"	0.083
—	—	43	—	0.069
135	18	43	Normal	0.174
150	12	44	"	0.182
—	—	43	—	0.157

The effect of Heat Treatment on the Virus Content

The virus content was determined by means of the half leaf method described previously.¹ There were three series of experiments. Each series consisted of three experiments. In each case the lesion count of each of two heat treatments was compared with that of untreated seed; also lesion counts of 67 (first series) or 50 (second and third series) untreated seeds was compared with that of 200 untreated seeds to indicate the relation between lesion count and amount of virus. For each series the *Nicotiana glutinosa* plants were pricked out and potted into the same soil and watered in the same way. An experiment was completed on the same day. In the case of the second and third series the suspension was diluted to 30 ml. The data obtained are given in Table II.

TABLE II

THE EFFECT OF HEAT-TREATING VIRUS-INFECTED TOMATO SEED IN NORMAL ATMOSPHERE ON THE VIRUS CONTENT. AFTER THE THIRD TREATMENT THE SUSPENSION WAS THREE TIMES AS DILUTE.

Treatment		Experiment	Number of Lesions		Relation between Lesion Count and Amount of Virus	
Temperature ° F.	Duration (Days)		Treated Seed	Control Seed	Number of Lesions	
					67 Seeds	200 Seeds
150	6	1	240	590	404	390
		2	618	700	207	401
150	4	1	275	586	404	390
		2	417	358	684	694
150	2	1	362	383	207	401
		2	270	629	684	694
		50 Seeds				
135	9	1	56	58	1	120
		2	97	121	118	89
135	6	1	38	140	1	120
		2	61	34	49	53
135	3	1	33	36	118	89
		2	109	80	49	53
150	12	1	65	62	73	186
		2	135	268	40	100
135	18	1	22	93	73	126
		2	76	209	254	119
120	8½	1	202	167	40	100
165	8½	2	136	250	254	119

Using all the data for obtaining relations between lesion count and amount of virus it was calculated that if the lesion count for 200 seeds ground in 10 ml. of water (the suspension not being diluted) was 100 that for 33 seeds was 77. A curve was drawn through the origin and these two points and used for obtaining the percentage of virus inactivated. All the data in the case of the 135° F. and 150° F. treatments was used to give a relation between logarithm

$\frac{\text{Amount of virus at time 0}}{\text{Amount of virus at time t}}$

and length of heat treatment for 142.5° F., the mean temperature. The relation is exhibited in Fig. 2. Neglecting the effect on the seed itself the relation should be a straight line through the origin and so the line of best fit was drawn through the three points and the origin.

The line gives a half time of 5.5 days, i.e. in 5.5 days the virus content is reduced to half; in 22 days it would be reduced to less than 10 per cent. (6.25 per cent.). All heat treatment cures have involved heat treating for about this period of time *but* as mentioned below deterioration of the treated material may increase susceptibility to virus infection.

Seed should be heat treated for one month and sown to determine if infected plants arise. In a preliminary experiment this year seed transmission occurred at the third truss stage.

Jozefowicz² found that preheating seed at a lower temperature decreased the harmful effect of treatment at a higher temperature. Hence the last treatment was given, but there was no important effect on the virus content.

TABLE III
THE EFFECT OF HEAT-TREATING VIRUS-INFECTED LETTUCE SEED ON THE SEED (ITSELF)

Treatment			Number of Seeds which had germinated out of 45, 17 Days after Sowing	Appearance of Seedlings	Average Weight of Seedling (Gms)
Relative Humidity	Temperature ° F.	Duration (Days)			
100	115	15	29	Normal	0.035
100	125	11	16	"	0.023
—	—	—	42	"	0.065
Normal	135	8	40	Normal	0.187
"	150	8	38	"	0.263
"	165	8	30	"	0.120
—	—	—	38	"	0.187
Normal	135	16	36	Normal	0.098*
"	150	16	34	"	0.045
—	—	—	36	"	0.62
Normal	135	24	38	Normal	0.0208
—	—	—	40	—	0.0265

* Later the average weight of a plant was 3.7 gm., of a control plant 1.93 gm.

Lettuce seed

Sixty grams of Winter Crop lettuce seed was thoroughly mixed. Virus was shown to be present by grinding a sample of the seed in a small amount of water and treating young lettuce plants dusted with carborundum. Samples of the seed were subjected to various heat treatments.

The effect of Heat Treatment on the Seed itself

Heat treatment of the seeds in an atmosphere saturated with water vapour had a harmful effect upon the seedlings, but the injurious effect was less marked when heating took place in a normally dry atmosphere. As in the case of the tomato short periods of heating at the lower temperatures increased the weight of the seedlings from the treated seeds. In all cases the seedlings were slightly paler in colour after the seeds had been submitted to heat treatment. The data are given in Table III.

The effect of Heat Treatment on Percentage of Plants Infected

Untreated seeds and also those from the following treatments in normal atmosphere were sown and kept under observation: Eight days at 135° F., 150° F., and 165° F.; 16 days at 135° F. and 150° F.; and 24 days at 135° F. Table IV records the results.

TABLE IV
THE EFFECT OF HEAT-TREATING VIRUS-INFECTED LETTUCE SEED IN NORMAL
ATMOSPHERE ON PERCENTAGE OF PLANTS INFECTED

Treatment		Number of Plants infected out of 150	
Temperature ° F.	Duration (Days)	From Treated Seed	From Untreated Seed
135	8	7	18
150	8	3	7
165	8	4	4
135	16	6	4
150	16	7	4
135	24	2	1

None of the treatments reduced the amount of infection considerably, but there was an indication that the higher the temperature the greater the percentage of infected plants and that a minimum percentage of infected plants may be associated with a definite duration of heat treatment.

After a month from sowing in autumn and winter no more lettuce mosaic symptoms appeared on the plants. It seems that strict roguing during that period will eliminate most of the disease. Infected plants are easy to distinguish by bronzing of the leaves.

During one year infected seed became almost free of virus which could infect the seedlings.

(b) Chrysanthemum Mosaic Disease

The chrysanthemum virus disease, chrysanthemum mosaic, first reported by Ainsworth is being investigated further. Ainsworth, who identified this disease in 1938³, observed a slight light green, occasionally yellowish mottling of the upper leaves. He regarded the virus as a strain of cucumber virus capable of inducing a much greater distortion in *Nicotiana glutinosa* than the type virus.

In 1939 Selman first noticed the effect of the virus on the flower⁴ describing discolouration, distortion, dwarfing and "breaking" of the colours. He found that symptoms on the leaves were almost totally absent, except for a few leaves showing a faint, chlorotic mottling. He reported a slight reduction in leaf size. Tomato plants inoculated with the virus exhibited "fern leaf" symptoms, and Selman thought it possible that the virus was a new one. He warned growers to keep plants free from aphids.

Smith⁵ reported that a diseased chrysanthemum plant is stunted and that the leaves show a mottle of dark green on the lighter, normal shade. The virus would not infect the cucumber but is related to cucumber mosaic virus. He mentioned that the virus had a wide host range. An infected tomato plant exhibited a yellow pallor and there were enations on the leaves. Distortions were produced in Petunia. He showed that the virus is transmitted by the aphid, *Myzus persicae*.

The present work is being carried out under the headings: (a) Symptoms; (b) Varieties Affected; (c) Host Range and Nature of Virus; (d) Transmission; (e) Therapy.

Plants with bloom distortion were tested for mosaic virus. Symptoms of disease in the case of plants which were found infected were recorded and are given in Table V. Infected blooms are illustrated in Figs. 3-6.

The symptoms of chrysanthemum mosaic disease may be summarised as follows:—

(1) FOLIAGE

There were no definite symptoms on the foliage that can be used for diagnostic purposes.

Sometimes there was a light and dark green mottling, a slight yellow mottling and also a yellowing of the veins, but these may have been due to other causes.

(2) FLOWERS

(a) Asymmetry and stunting of the entire bloom.

(b) Fewer florets.

(c) Slow rate of unfolding of the petals especially in the centre of the bloom.

(d) Distortion, unevenness, narrowing, rolling and quilling of the florets.

(e) Tousled, (untidy) appearance of the blooms and change of incurved or reflexed character.

(f) Colour breaking especially in red and bronze varieties: loss of colour value.

TABLE V
SYMPTOMS OF MOSAIC INFECTED CHRYSANTHEMUM PLANTS

Variety	Bloom Characters	Nature of Plant	Foliar Symptoms	Bloom Symptoms
American Beauty ...	White incurved florets.	Branches from a grower.	(a) Slight aucuba mosaic. (b) Distorted foliage having paler green areas.	Asymmetrical bloom. Quill florets in untested blooms.
Marie Morin ...	White reflexed florets.	Stem cuttings. Second year growth.	No symptoms.	Distorted blooms.
Snowdon ...	White reflexed florets.	Stem cuttings.	" "	Bloom smaller. Florets distorted.
Blazing Gold ...	Yellow incurved florets.	Second year growth. " "	Foliage normal (but has yellow spots, some brown).	Distorted bloom.
Friendly Rival ...	" "	" "	No symptoms.	Bloom stunted. Narrowing of florets.
Jane Ingamells ...	" "	" "	Slight light and dark green mottling.	Narrower quill florets which have lost incurved nature.
Golden Coralie ...	" "	" "	No symptoms.	Distorted florets.
Winn Quinn ...	" "	" "	" "	Incurved nature of floret less developed.
Imperial Yellow ...	" "	" "	" "	Some irregularity of florets.
Orange Glow ...	Orange incurved florets.	Stem cuttings.	" "	Some blooms are asymmetrical and smaller, the centre remains closed and surface of corolla of floret is uneven.
Tibshelf Glory ...	Light bronze reflexed florets.	Second year growth. Basal cuttings.	" "	Bloom stunted, asymmetrical, lost incurved nature of floret, colour break—pink present.
Gladys Paine ...	Pink reflexed florets.	Second year growth. Stem cuttings.	Light and dark green mottling. No symptoms.	Floret narrower curved upwards and inwards. Bloom short of florets. Florets not uniformly arranged. Colour break—cream present.
August Pink ...	Pale pink reflexed florets.	Branches from grower.	(a) No symptoms.	Only abnormality has been a colour break—white present.
Rose Harrison ...	Pink reflexed florets.	Second year growth.	(b) Occasional clearing of veins. If anything slight pale aucuba mosaic.	Irregular size of florets. Colour break—white and yellow present.
Mary Mona ...	" "	Stem cuttings. Second year growth.	No symptoms. Light and dark green mottling.	Asymmetrical bloom. Colour break—yellow present.
Shirley, Late Red ...	Red reflexed florets.	" "	No symptoms.	Narrowing of florets. Colour break—yellow and creamy-white present—on untested blooms.
Valiant ...	" "	" "	Yellowing of leaf veins.	Distorted bloom.

TABLE VI
SYMPTOMS DUE TO CHRYSANTHEMUM MOSAIC VIRUS IN OTHER HOSTS

Family	Species	Date Plants Treated	Date	Description of any Symptoms of Disease
Chenopodiaceæ ...	<i>Beta vulgaris</i> (Garden Beet) ...	30/4/51	29/5/51	No symptoms appeared.
Cucurbitaceæ ...	<i>Cucumis sativus</i> (Cucumber) ...	24/8/51	24/9/51	" " "
		7/11/51	11/12/51	" " "
Leguminosæ ...	<i>Vicia faba</i> (Broad Bean) ...	23/4/51	29/5/51	" " "
	<i>Lupinus angustifolius</i> (Lupin) ...	30/4/51	29/5/51	" " "
	<i>Phaseolus vulgaris</i> (French Bean) ...	24/7/51	21/8/51	" " "
	<i>Pisum sativum</i> (Garden Pea) ...	23/4/51	29/5/51	" " "
	<i>Lathyrus odoratus</i> (Sweet Pea) ...	23/4/51	29/5/51	" " "
	<i>Trifolium repens</i> (White Clover) ...	30/4/51	29/5/51	" " "
	<i>T. pratense</i> (Red Clover) ...	30/4/51	29/5/51	" " "
Compositæ ...	<i>Callistephus chinensis</i> (China Aster) ...	9/4/52	28/4/52	Yellowish green-green mottle
	<i>Calendula</i> sp. (Marigold) ...	28/4/51	29/5/51	No symptoms appeared
	<i>Dahlia</i> sp. ...	23/4/51	29/5/51	" " "
	<i>Zinnia elegans</i> (Double) ...	9/9/51	24/9/51	Light and dark green mottling of foliage, uneven surface of same.
	<i>Lactuca sativa</i> (Lettuce) ...	18/1/51	8/10/51	Yellowing of head.
		17/3/51	15/2/51	No symptoms appeared.
Primulaceæ ...	<i>Primula obconica</i> ...	10/7/51	16/4/51	" " "
			16/8/51	Leaves exhibiting light and dark green mottling.
Solanaceæ ...	<i>Primula sinensis</i> ...	10/7/51	16/8/51	No symptoms appeared.
	<i>Nicotiana tabacum</i> (Tobacco) ...	17/3/51	9/4/51	Leaves have yellowish green mottle and bubbly appearance.
			Later	Yellow mottle.
	<i>N. glutinosa</i> ...	16/1/51	19/3/51	Leaves exhibiting yellowish green mottle and bubbly appearance.
			28/3/51	Narrowing of lamina.
			Later	Small enations on lower surface of leaves.
		7/2/51	28/3/51	Leaves exhibiting symptoms.
		Day at end of June	7 days later	Vein clearing.
			10 days later	Mottle.
		Day in November	3-4 weeks later	Mottle.
		Day in winter, '52	5 weeks later	Mottle—glasshouse warmer.
	<i>Lycopersicum esculentum</i> (Tomato) ...	7/2/51	2/4/51	Fern leaf symptoms. No enations.
	<i>Solanum nigrum</i> (Black Nightshade)	24/7/51	16/4/51	Tendrill leaves present.
			31/7/51	Yellowing of top.
			21/8/51	Slight yellow mosaic.
	<i>Datura stramonium</i> (Jimson Weed)	8/6/51	18/6/51	Yellowish green circular spots on leaves.
			26/6/51	White dots each surrounded by pale green area on leaves.
			3/7/51	Yellowish green rings on upper leaves.
	<i>Petunia</i> sp. ...	28/4/51	16/5/51	Vein clearing.
			21/5/51	Leaves exhibiting bubbly surface and whitish areas.
			29/5/51	Narrowing of leaf, upcurling of margin of same, enations on its lower surface.
Scrophylariaceæ ...	<i>Antirrhinum major</i> (Snapdragon) ...	23/4/51	29/5/51	No symptoms appeared.

The widespread occurrence of the disease is shown by the following list of varieties reported showing bloom distortion:—

American Beauty, Annie Curry, Appert, August Pink, Autumn Gold, Baldock's Crimson, Barbara, Blazing Gold, Bronze Harrison, Bronze McCleod, Capt. Kettle, Cheshunt White (Autocrat), Christmas Beauty, Commando, Conqueror, Exmouth Crimson, Florina, Favourite Supreme, Friendly Rival, Gladys Paine, Goldenbloom, Golden Coralie, Huntsman, Imperial

Pink, Imperial Rose, Imperial Yellow, Jane Ingamells, Marie Morin, Market Gem, Market Gold, Mary Mona, Molly Nicholson, Monument, Morning Glow, Oldland Crimson, Orange Glow, Picture, Pink Favourite, Radiant, Red Favourite, Rose Harrison, Royal Bronze, Salmon Favourite, Santa Claus, Solomon, Tibshelf Glory, Valiant, White Favourite, Winifred.

A range of species were inoculated with the virus of chrysanthemum mosaic. Six young plants of each were dusted with carborundum and then treated with chrysanthemum mosaic virus solution obtained for convenience by grinding *N. glutinosa* leaves in 0.5 per cent. sodium sulphite, the *N. glutinosa* plants having been infected previously with virus from an infected chrysanthemum. In the case of the cucumber plants treated on August 24th, 1951, virus solution was introduced through a hypodermic needle inserted in each of three plants. The plants were observed weekly for not less than one month. Table VI contains the results of these experiments.

There are many points of difference both in susceptibility and symptoms exhibited by certain plants after infection with chrysanthemum mosaic virus and cucumber virus 1 respectively. For instance, the different symptoms on *N. glutinosa* and *Datura stramonium* should be noted.

Chrysanthemum mosaic virus produces on *N. glutinosa* a mottle followed by great distortion: ordinary cucumber mosaic virus only causes a mottle. In the case of *D. stramonium* the former virus induces circular spots, the latter one a mosaic mottle.

The best test plant is *N. glutinosa*. It develops a mottled appearance in winter at low temperatures in seven weeks, and at higher temperatures in five weeks after inoculation: in summer the period is 10 days and in autumn three to four weeks.

Transmission

(1) FROM CHRYSANTHEMUM TO *N. GLUTINOSA*

It was shown that both 0.5 per cent. sodium sulphite and carborundum are necessary for transmission from chrysanthemum to *N. glutinosa*.

(2) FROM *N. GLUTINOSA* TO *N. GLUTINOSA*

N. glutinosa plants are being used as stock plants. Transmission from *N. glutinosa* to *N. glutinosa* occurs using either the virus dissolved in water and plants dusted with carborundum or sulphite solution added to the virus and no carborundum.

(3) FROM *N. GLUTINOSA* TO CHRYSANTHEMUM

It has *not* been found possible to transmit mechanically the virus from *N. glutinosa* to chrysanthemum.

Chrysanthemum mosaic virus in 0.5 per cent. sodium sulphite was applied to six chrysanthemum plants dusted with carborundum. One month later the plants were tested and none found infected. This work will be repeated.

An attempt was made to obtain infection by causing virus solution to be sucked into chrysanthemum plants by means of transpiration.

Two methods were investigated. In the first the lamina as far as the midrib and the tip of a leaflet of each of three tomato plants were cut off. The plants were wilting slightly. The midrib was inserted into a solution of tomato aucuba mosaic virus and left there for two days. One ml. of liquid entered but one month later the plants had not developed symptoms of infection. When the experiment was repeated with malachite green solution it was found that the liquid passed into the neighbouring leaflets. The experiment was repeated with virus solution but this time on removal of the midrib from the solution the neighbouring leaflets were squeezed to allow virus to pass from the xylem into the mesophyll. Again the plants remained clean. The second method involved inserting a hypodermic needle attached by rubber tubing to a thistle funnel containing tomato aucuba mosaic virus solution into the axil of a leaf of each of six tomato plants for two days. The plants were slightly wilting. One ml. of liquid entered. Using malachite green solution it was shown that the dye passed to the top of the plant. Two plants became infected.

Thirty chrysanthemum plants of five varieties had chrysanthemum mosaic virus in 0.5 per cent. sodium sulphite introduced into them by the last method. In each case the needle remained unblocked. Two months later 15 of the plants were tested and found free from disease. The 30 plants were intended for recording symptoms and therapy experiments.

The work is being continued.

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III. ENTOMOLOGICAL INVESTIGATIONS

I. RED SPIDER MITE (*Tetranychus telarius* L.)

By E. R. SPEYER and W. J. PARR

During the many years over which Red Spider mite has been kept under observation, much more attention has been devoted to ways and means of exterminating this pest of glasshouse plants than to a study of its reactions to varying conditions of environment. An attempt is therefore being made to obtain some information as to how long adult mites of the summer form will live and as to the number of eggs the females will lay when they are exposed to excess or lack of moisture, when they are deprived of food, and when they are transferred from the host-plant upon which they have been reared to the leaves of other plants. The results of some preliminary experiments are here recorded, together with some observations upon the method of oviposition and the effects of excess and lack of moisture upon the viability of the eggs.

Source of Material.—The mites were obtained from carnation pot-plants grown in a small glasshouse; a considerable infestation had developed at the beginning of April, and in order to maintain the stock, uninfested plants were from time to time placed amongst the original batch. When mites from tomato and cucumber were made use of, these were collected from plants growing in the experimental houses at the Cheshunt Station.

All observations were recorded in the laboratory in absence of direct sunlight. Temperatures were recorded throughout by means of a thermograph.

In order conveniently to transfer mites from the plant upon which they were living to new surroundings, the following procedure was adopted. A leaf upon which mites were present was cut from the plant and placed upon the stage of a low-power binocular microscope, by means of which the sexes could be separated, and individuals which had at least recently become mature could, by their general appearance, be distinguished from those which had attained a considerable age.

Each selected mite was lifted from the leaf surface upon a narrow pointed strip of paper (about $\frac{1}{2}$ in. in length) held in forceps. When the pointed end of the strip was thrust between the body of the mite and the leaf-surface, the animal would cling to and begin to ascend it, and the strip was then rapidly laid upon the surface or dropped into the receptacle to which it was desired to introduce the mites. A mite could be lifted in similar manner upon a needle from which, on jarring during its ascent the animal would fall, and remain suspended by the anterior end of the rostrum upon a thread of webbing which the mite had trailed after attaching it to the needle point. Difficulty was encountered in separating the mite from the thread after it had been lowered on to the desired surface.

The use of the paper strip was therefore far more satisfactory.

A needle or fine brush was used to transfer female deuteronymph resting stages from leaf to leaf; by this means unfertilized females were obtained, and males were placed on the leaf with the deuteronymphs when fertile females were required.

(1) Mites deprived of Food and Moisture

Numbers of mites were introduced into glass vials, each 3 ins. long by $\frac{1}{2}$ in. diameter, the open end provided with a waxed cork through which a hole had been bored to contain a glass tube, with the end projecting into the vial drawn out in order to admit air and prevent easy escape of the mites. The precautions against escape were not wholly successful, but sufficient numbers of mites remained in the vials for the purpose in hand.

The experiments were conducted in April at a mean temperature of 63° F. with a maximum and minimum respective of 72° F. and 58° F. With the prevailing atmospheric humidity the average life of four females was six days (range 5–6 $\frac{1}{2}$ days) and of three males, three days (range 1 $\frac{1}{2}$ –4 days).

In a dessicator, over calcium chloride, and only removed for short daily inspection, three females survived for five days, and were dead on the sixth day; of two males, one was dead on the fourth, and the other on the fifth day. A female which had assumed the red colouration of the hibernating form remained alive for 11 days.

In the vials, the males wandered over the surface of the glass, while the females spun a quantity of webbing amongst the strands of which they lived.

(2) Mites deprived of Food but with access to Water

Circular cork discs, $\frac{1}{2}$ in. or more in diameter and about $\frac{1}{8}$ in. thick, of which one surface and the perimeter had been covered with a layer of paraffin wax, were floated with the unwaxed surface upwards upon water contained in an uncovered petri dish or solid watch-glass. It was considered very unlikely that mites kept upon the discs could obtain any sustenance from the cork, but they could readily obtain water, since the wax in no way interfered with their movements. The meniscus formed round the waxed perimeter provided an efficient barrier whereby the mites were prevented from making their escape from the discs.

In April and May, with a mean temperature of 62° F. (range 56° F.–72° F.), five females kept upon a smooth cork surface remained alive for an average-period of 12 days (range 11–15 days) and deposited in all 10 eggs (seven upon the cork surface and three upon its waxed perimeter). Five males survived for an average period of 11 days (range 6–14 days). The mites tended to remain upon the waxed perimeter of the disc, often actually in contact with the surrounding water; the females made attempts to spin webbing over the surface of the water, upon which they were frequently found to be floating. At least the majority of the eggs deposited were viable.

In May, with a mean temperature of 60.5° F. (range 56° F.–66° F.), five females kept upon a roughened cork surface remained alive for an average period of 13 days (range 10–16 days), during which they deposited in all seven eggs, all but one of which hatched with an incubation period of 10–13 days. The mites lived in webbing spun over the cork, upon which all the eggs were laid.

The results obtained indicated that the amount of food obtained from the foliage of carnation plants upon which they had previously been living sufficed to keep the mites alive for periods up to at least 10 days, provided that they had access to water; the numbers of eggs deposited (some two per female) was small, but the adverse conditions under which the females were kept affected neither the viability nor the period of incubation of such eggs as were laid.

(3) Submergence in Water

Some difficulty was encountered in inducing the mites to sink in water. The surface tension was most easily overcome by floating a mite on water contained in a solid watch-glass and pushing it beneath the surface by repeated thrusts with a pointed strip of wet filter-paper. Mites which burst during the process appeared to be only those which had become greatly distended with food or eggs. Addition of a wetting agent such as Agral to the water in no way facilitated the sinking of the mites. After the surface tension had been broken, a considerable quantity of air often enveloped the forelegs and mandibular plate and was at least partially removed by bringing the mite to the surface on a fine brush and sinking it again with the paper strip. Small air-bubbles still adhering to portions of the integument dissolved in the surrounding water within at most a few hours.

In the latter part of April, adult females collected at random from carnation plants, and therefore of uncertain age, were submerged in 1–2 ml. water for periods ranging from two hours to nine days, addition being made frequently to compensate for evaporation during the longer periods. At recorded intervals, the mites were transferred on a fine brush to tomato leaf-discs floating upon water.

On submergence the mites soon became quiescent, and remained motionless for some 30 minutes; within three hours, however, they became active, and usually the vigorous movements of their legs were ceaseless for subsequent periods of at least three hours. Of the mites submerged for the longer periods, the majority continued to move their legs actively and apparently unceasingly up to the seventh day, and on the ninth day three out of seven mites were still making feeble movements. No mites were actually killed by submergence for periods up to seven days.

After removal from the water to the leaf-surface and even after short periods of submergence, movement ceased, but the mites became active, or at least partially regained their power of movement, within from two minutes to one hour, and eggs were deposited from one to six hours later by some females which had been submerged for periods up to 24 hours. After submergence for three days or more, the mites never resumed their full activity, though they might well have done so had they been transferred to the foliage of growing plants and kept under more favourable conditions of temperature.

For females which had not been submerged or which had been submerged for periods up to 24 hours, the principal period of oviposition extended over the first three to four days after they had

been placed upon the floating leaf-discs: after submergence for two to three days, the very small number of eggs produced were all deposited within 24 hours.

Five male mites transferred to a floating leaf-disc after submergence for 48 hours lived for an average period of five to six days (range 4-9 days): their behaviour during submergence was similar to that of the females.

From the results of the observations, which are summarised in Table I, there are indications that both the reproductive capacity of the females and viability of eggs deposited by them were progressively reduced in proportion to the increasing periods of time during which the mites had remained submerged. On the other hand, if the period of submergence is, in each case, added to that of subsequent survival, it becomes apparent that, irrespective of the period of submergence, the average longevity of the mites was not significantly decreased as compared with that of mites which had not been subjected to such treatment.

TABLE I
SUBMERGENCE OF FEMALE MITES IN WATER

Number of Mites Used	Period of Submergence	Temperature (mean) during Submergence ° F.	Survival (in days) after submergence		Eggs Deposited		
			Mean	Range	Total	Average per Female	% Viable
5	Nil	—	12.2	9-17	16	3.2	100
4	2 hours	61.5	12.3	8-15	10	2.5	90
10	4 "	60.7	12.5	5-17	15	1.5	80
11	24 "	62.3	10.8	6-21	16	1.5	69
10	48 "	63.6	10.9	4-27	6	0.6	33
5	72 "	64.5	8.6	4-12	6	1.2	33
5	6 days	62.0	5.0	2-9	1	—	0
7	9 "	62.0	2.7	0-6	0	—	—

On April 18th, five females in the deuteronymph resting stage were submerged in 1 ml. water for a period of 24 hours, and then transferred to a leaf-disc floating on water. Within 17 hours two and within 44 hours the other three mites had performed the ecdysis to the adult stage. The mites were active and lived for an average period of 17.2 days (range 9-26 days). On the thirteenth day, males were placed upon the leaf-disc with the three females then surviving, but mating was not observed to take place. None of the females deposited a single egg.

Since it was later established that unmated females deposited at least as many eggs (of which a very high percentage were viable) as mated ones when kept on floating leaf-discs, the mites appeared, in this particular instance, to have been rendered sterile by previous submergence of the deuteronymph in water.

On May 29th a female mite was submerged to a depth of about 5 mm. in distilled water contained in a solid watch-glass provided with a glass cover. In order to examine it periodically, under magnifications up to some 350 diameters, the mite was drawn into a pipette, transferred in a drop of water to a large thin cover-glass used in place of a microscope slide and a small cover-slip was lowered on to the drop, care being taken not to subject the mite to too great pressure by adding distilled water at the edge of the coverslip: an examination of both dorsal and ventral aspects was made possible by quickly inverting the "preparation."

On submergence, the mite moved its legs vigorously for a period of three minutes, and then became quiescent with legs fully extended and later slightly bent. Examined after 45 minutes, when all small air-bubbles previously adhering to portions of the integument had dissolved in the water, air was seen to be present only in transverse furrows in the arc formed by the peritreme of each side and in longitudinal furrows extending from these to the apex of the mandibular plate.

No air appeared to be present in the peritremes themselves up to their junction with the main tracheal trunks beneath the surface of the cuticle;* the internal tracheal system was silvery in appearance. The air in the furrows referred to persisted, apparently without diminution, over the whole period of 13 days during which the mite remained submerged. The mean temperature recorded over this period was 65° F. with a range of 59° F. to 72° F.

* In other submerged specimens of both sexes, the lumen of the peritremes contained air or gaseous matter which persisted in them at least for several days.

The mite was often found to be moving its legs vigorously, and certainly did so whenever disturbed, up to the twelfth day of submergence, and on the eleventh day voided the excretory pellets which had been contained in the hind-gut.

On the thirteenth day the mite was motionless and made no response to stimulus: some maceration of the internal organs had probably taken place, since the cuticle burst while it was under examination.

The results obtained from the foregoing observations show that submergence of adult mites in water has little if any effect in curtailing their normal span of life. After submergence for periods of 24 hours or more, it appeared probable that eggs which had matured in the ovary previously were deposited, but that further production of eggs ceased altogether. After 24 hours' submergence, females in the deuteronymph resting stage performed the ecdysis to the adult stage, but though they survived subsequently for periods up to 26 days, they deposited no eggs.

(4) Mites kept upon Floating Leaves

The keeping of mites under observation and the counting of the eggs laid by them upon the foliage of growing plants, even of small size, is most laborious. The simple "flotation" method devised by Callan (1947) for the rearing of certain insects suggested itself as possibly applicable to the study of the mite.

The method involves the use of petri dishes or solid watch-glasses containing water upon the surface of which a leaf, or portion thereof, is floated. When mites were placed upon floating leaves, it became apparent that the meniscus formed round the edges prevented their escape, and that when they succeeded sometimes in overcoming the barrier, they would float upon the water in contact with or very near the edge, whence they could easily be returned to the leaf surface. Often the mites were restless when first introduced to their new environment, but became accommodated to it within a day or two.

If glass covers were placed over the receptacles, the degree of atmospheric saturation and condensation of moisture produced caused the mites to lose all powers of movement: adult mites kept for some 48 hours under such conditions regained their activity within about 10 minutes after the covers had been removed and suffered no appreciable injury, since they survived for as long as, and the females laid a number of eggs comparable with that of mites which had not been subjected to such treatment. Open receptacles were therefore employed, with a well-raised cardboard cover for protection against excessive deposit of dust and from direct sunlight.

During observations of an exploratory nature, which extended over a period from April 9th to May 26th the mean daily temperatures fluctuated between 60° F. and 68° F., with a range of 56° F. to 72° F. Since males occurred in very considerable numbers upon the carnation plants from which the mites were obtained, the females had in all probability been mated.

(a) A female kept upon a portion of a carnation leaf (about $\frac{3}{4}$ in. by $\frac{1}{4}$ in.) floating with under-surface upwards deposited 19 eggs over a period of 13 days: it was then transferred to a fresh leaf ($2\frac{1}{4}$ ins. by $\frac{1}{4}$ in.) floating under-surface upwards, upon which it deposited 12 eggs during the ensuing seven days. Over the whole period of 20 days, at least one but not more than three eggs were laid daily. After this, no further eggs were laid, and the mite was dead four days later, having survived for 24 days and laid in all 31 eggs, which, for the most part, were deposited in close proximity with one another. All the eggs hatched subsequently, the period of incubation ranging from 10 to 16 days.

(b) A female transferred to a smooth leaflet ($1\frac{1}{4}$ ins. by $\frac{1}{2}$ in. greatest width) cut from a tomato seedling floated under-surface upwards lived for 13 days and deposited 10 eggs, all of which hatched with an incubation period of 10 to 13 days. The eggs were widely scattered over the leaf-surface, and not more than two were laid on any one day.

(c) Five females were transferred to an older tomato leaflet ($2\frac{3}{4}$ ins. by $1\frac{1}{2}$ ins. greatest width) floated under-surface upwards. On the eighteenth day one female was dead and 20 eggs had been deposited. The four surviving mites were then transferred to a fresh leaflet of nearly similar dimensions: during the ensuing period of 12 days two mites died and 14 eggs were deposited. After transference to a third leaflet, upon which two eggs were subsequently laid, one mite was dead on the thirty-fifth day, and the other on the thirty-ninth day from the start of the experiment.

The average life of the five females was 29 days, with a range of 17 to 39 days. In all, 36 eggs were deposited, all but one (the last laid) of which hatched with an incubation period of nine to 15 days; they were generally distributed over the leaf-surface.

A male, transferred to the first leaflet lived for 14 days, and five males kept upon the second leaflet had an average life of 12 days, with a range of eight to 16 days. None of these were observed to mate with any of the females.

(d) Four females, transferred to a disc ($\frac{1}{2}$ -in. diameter) cut out from a tomato leaflet and floated under-surface upwards, deposited 13 eggs over a period of 10 days. One female was dead upon the tenth day, when the remainder were alive and active. In this instance further observations were not recorded, but on two similar discs floated upon a nutrient solution, and upon which 10 eggs had been deposited, all these hatched with an incubation period of 12 to 15 days.

Some adult mites were also kept upon carnation leaves and tomato leaflets floating upon a standard nutrient solution containing 200 p.p.m. potassium as K_2O . The solution did not cause the leaf-tissues to remain fresh for longer periods than those of leaves floated upon water: the period of survival of the mites was shorter and the number of eggs laid by the females was significantly smaller, though their viability was not impaired.

It was concluded that adult mites of both sexes would survive for long periods of time and that the females would deposit considerable numbers of eggs upon leaves detached from plants and floated upon water, even if they were confined within a comparatively small area of leaf-surface.

Whereas more than 30 eggs were deposited by a single mite upon floating carnation leaves, the number laid by females after transference from carnation plants to floating tomato leaflets was small, averaging some eight eggs per mite. In all cases, a very high proportion of these eggs were viable.

As a result of these observations, it was considered likely that useful information might be obtained by recording the longevity and reproductive capacity of the mites in a series of experiments in which females were transferred from a particular host-plant upon which they had been bred for several generations to floating leaves of the same and of other kinds of plant.

The experiments were conducted in the laboratory during July, August, and early September, the plants selected being carnation, tomato, and cucumber.

Portions of carnation leaves, some 1 to 2 ins. in length, were floated with their under-surface upon the water: the leaf-tissues remained in good condition for very long periods of time, but after 10 to at most 14 days the mites were transferred to fresh ones upon which they were kept for from six to nine days, and in cases in which large numbers of eggs were deposited to a third leaf.

Discs about $\frac{3}{4}$ in. in diameter cut out of tomato leaflets and cucumber leaves were floated under-surface upwards, and as their tissues showed signs of deterioration after some 14 days, the mites were transferred to fresh ones after periods of 10 to at most 13 days in the case of tomato, and after three to eight days in the case of cucumber.

To ensure that the mites had deposited no eggs prior to their transference, use was made only of females in the deuteronymph resting stage, which performed the ecdysis to the adult stage within a day or two after they had been placed upon the floating leaves. The method also made it possible to carry out observations upon virgin and fertile females respectively, the latter being obtained by keeping males upon the leaves with the deuteronymphs: these were observed to mate with the females during or immediately after the ecdysis, the sexes remaining *in coitu* for from two to six minutes; only one pairing took place. The mites usually established themselves readily upon floating carnation leaves, on which, judging by the rapidity with which the surface "bloom" was removed, they fed extensively and they laid down considerable quantities of webbing.

When mites, bred upon tomato plants, were transferred to tomato leaf-discs, they also soon themselves established, but those previously reared on carnation took some time to do so. Their rate of accommodation to cucumber leaf-discs was erratic. The amount of webbing spun upon tomato and cucumber leaf-discs appeared to be less than on carnation leaves.

It was not possible to assess the amount of feeding which took place either upon tomato or cucumber leaf-discs, but in neither case did this appear to be at all extensive.

Whether mated or unmated, the females deposited their first eggs from one and a half to three and a half days after the ecdysis from the deuteronymph resting stage.

Upon floating carnation leaves the females tended to be gregarious, so that large numbers of eggs were deposited in close proximity with one another, while on tomato and cucumber leaf-discs this was not the case, and the eggs were scattered generally over the whole surface.

In Table II the longevity of the female mites is recorded, and although the full span of life was not obtained in all cases, there is sufficient indication that the period of time over which the mites

remained alive was not significantly influenced either by the plant of their origin or by the kind of leaf upon which they were kept: there was, perhaps, a tendency for virgin females to survive for rather longer periods of time than mated ones.

TABLE II
LONGEVITY OF FEMALE MITES ON FLOATING LEAVES

Females			Span of Life in Days	
From	On Leaves of	Number and Condition	Average	Range
Carnation ...	Carnation	{ 3 virgin	26.0	18-31
		{ 5 mated	18.8	14-21
	Tomato	{ 5 virgin	17.0	13-22
		{ 5 mated	15.4	10-22
Tomato ...	Cucumber	5 mated	< 20	—
	Tomato	{ 5 virgin	< 21	15-<22
		{ 5 mated	< 20	13-<22
	Carnation	{ 5 virgin	< 19	7-<22
Cucumber ...		{ 5 mated	18.5	9-23
	Cucumber	4 mated	< 18	—
	Cucumber	4 mated	< 14	—

On the other hand, there was divergence in the reproductive capacity of the mites upon floating leaves of the several plants.

From Table III, in which the results of the observations are recorded, it is seen that mites which had been bred upon carnation laid large numbers of eggs on floating leaves both of carnation and cucumber, whereas they deposited comparatively few upon those of tomato, irrespective of the kind of plant upon which they had been reared. The mites which had been bred upon tomato and were transferred to floating cucumber leaves again laid large numbers of eggs, but those which had been reared on tomato deposited only a small number upon floating leaves of carnation. In the experiment, the last in the Table, in which mites bred on cucumber were kept upon floating cucumber leaves, the number of eggs laid appears to be small, but, for some reason unknown, a considerable time elapsed before the mites would establish themselves upon the discs; this experiment had to be abandoned at a time at which there was a marked increase in the number of eggs which were being deposited.

Comparison of the numbers of eggs laid is best illustrated by reference to the column of Table III in which the daily average number of eggs calculated to have been deposited by a single mite over the period of oviposition is given.

On the average, unmated females deposited rather larger numbers of eggs than mated ones, and throughout a high proportion were viable. The percentage viability and the periods of incubation are given in Table IV.

Of the total of 1,528 eggs kept under observation, 1,456 hatched, giving a viability of 95 per cent. These comprised 426 eggs obtained from unmated females, of which 410 (96 per cent.) hatched, and 1,102 from mated females, of which 1,046 (95 per cent.) were viable.

At mean temperatures between 67° F. and 70° F., the average period of incubation was seven days (range 4-9 days), and between 64° F. and 66° F., 8.5 days (range 6-11 days), both for eggs obtained from mated and unmated females.

(5) Development of Young Stages on Floating Leaves

A large number of larvæ which hatched from eggs obtained in the experiments described above were kept under observation upon the floating leaves on which the eggs had been deposited.

Leaf-discs from cucumber had been floating for periods of from nine to 14 days when the first, and from 12 to 21 days when the last eggs hatched. Upon these the larvæ failed to complete the ecdysis to the protonymph stage, and succumbed within two or three days in contact with the meniscus or upon the surface of the water round the edges of the discs.

Discs from tomato leaflets had been floating for from seven to 13 days when the first, and from 14 to 20 days when the last eggs hatched. Usually the larvæ failed to develop beyond the protonymph

TABLE III
REPRODUCTIVE CAPACITY OF MITES ON FLOATING LEAVES

Females			Period of Oviposition			Eggs Laid		Temperature ° F.		
From	On Leaves of	No.	Condition	Dates	Days		Total	Daily Average per Mite	Mean	Range
					Mean	Range			Max.	Min.
Carnation	{ Carnation Tomato }	{ 4* 5 }	{ virgin mated virgin mated }	5, VII-3, VIII 12, VII-30, VII 6, VII-20, VII 7, VII-21, VII	21-25	10-30	291*	3.42	72.1	67.2
		{ 5 5 }			17-40	13-19	348	4.00	70.1	67.5
Tomato	{ Tomato Carnation }	{ 5 5 }	{ virgin mated virgin mated }	4, VIII-23, VIII 3, VIII-24, VIII 3, VIII-24, VIII 4, VIII-24, VIII	14-20	12-15	86	1.23	71.6	66.8
		{ 5 5 }			12-20	7-15	44	0.72	71.8	67.0
Carnation	{ Tomato Carnation }	{ 5 5 }	{ virgin mated virgin mated }	4, VIII-23, VIII 3, VIII-24, VIII 3, VIII-24, VIII 4, VIII-24, VIII	18-80	14-20	144	1.53	68.2	64.2
		{ 5 5 }			19-20	12-22	104	1.08	68.5	64.4
Tomato	{ Carnation Cucumber }	{ 5 5 }	{ virgin mated virgin mated }	20, VIII-6, IX 20, VIII-6, IX 25, VIII, 6, IX	18-80	6-22	62	0.66	66.1	62.72
		{ 5 5 }			17-20	8-21	43	0.50	68.1	64.1
Carnation	{ Cucumber Cucumber }	{ 5 5 }	{ mated mated mated }	20, VIII-6, IX 20, VIII-6, IX 25, VIII, 6, IX	18-00	—	319	3.54	66.6	62.5
		{ 5 5 }			16-80	12-18	261	3.11	65.4	61.8
Cucumber	{ Cucumber Cucumber }	{ 5 5 }	{ mated mated mated }	20, VIII-6, IX 20, VIII-6, IX 25, VIII, 6, IX	11-40	5-13	86†	1.51†	63.5	60-70

* One female lost on tenth day. † Record incomplete.

TABLE IV
VIABILITY AND INCUBATION PERIOD OF EGGS LAID BY MITES ON FLOATING LEAVES.

Female Mites			Eggs			Incubation in Days			Temperature ° F. during Incubation		
From	On Leaves of	Condition	No. in Sample	% Viable	Dates of Hatching*	Mean		Mean	Mean		Range
						Mean	Range		Max.	Min.	
Carnation	{ Carnation Tomato }	{ virgin mated virgin mated }	291 348 86 44	95.9 93.7 100.0 95.5	13, VII-10, VIII 19, VII-6, VIII 14, VII-27, VII	7.3	6-10	69.6	71.9	67.1	63-77
						6.8	6-8	70.3	72.5	67.8	63-76
Tomato	{ Tomato Carnation }	{ virgin mated virgin mated }	32 17 17 27	93.7 94.1 88.2 88.9	13, VIII-20, VIII 11, VIII-20, VIII 11, VIII-18, VIII 12, VIII-21, VIII	8.7	8-10	66.1	68.0	64.2	62-72
						8.0	7-10	66.6	68.5	64.6	62-75
Carnation	{ Carnation Cucumber }	{ mated mated mated }	319 261 86	97.2 93.9 96.5	29, VIII-14, IX 31, VIII-14, IX 5, IX-14, IX	7.8	7-9	66.4	67.9	64.7	62-72
						8.9	7-10	66.2	68.1	64.3	60-72
Tomato	{ Carnation Cucumber }	{ mated mated mated }	319 261 86	97.2 93.9 96.5	29, VIII-14, IX 31, VIII-14, IX 5, IX-14, IX	8.8	7-11	65.0	67.3	63.1	60-72
						9.0	7-11	64.5	66.7	62.8	60-72

* The periods over which the eggs were deposited are given in Table III.

stage, but out of 13 larvæ hatched from eggs laid by mated females (bred previously on carnation) upon one disc, two reached the female deuteronymph stage after a period of 11 to 12 days, during which the disc had been floating for from seven to 19 days: they failed to enter the resting-stage prior to the final ecdysis to maturity.

Upon portions of floating carnation leaves, very considerable numbers of larvæ obtained from eggs laid by females previously reared on carnation plants developed to maturity. Those which were the progeny of unmated females all developed to adults of the male sex, and on one leaf which had been floating for seven days prior to hatching of the first eggs, 12 out of 50 larvæ reached maturity in an average period of 12 days (range 8–14 days): on other leaves which had been floating for periods of seven to 10 days, many larvæ reached maturity in eight to 10 days, but development occupied a period of 14 days upon leaves which had been floating for 17 to 18 days prior to hatching of the eggs. From the eggs laid by mated females, the larvæ developed to adults of both sexes, probably with a considerable preponderance of females. On one leaf which had been floating for seven to 11 days previous to hatching of the first and last eggs respectively, 15 out of 23 larvæ reached maturity; two were males and 13 females, the period of development being 11 to 12 days for the former, and 12 to 15 days for the latter.

Larvæ which were the progeny of either mated or unmated females reared upon tomato plants, and which had hatched from eggs laid by the latter on floating carnation leaves failed to develop beyond the larval instar.

When larvæ were transferred from leaves upon which they had hatched to fresh floating leaves either of carnation or tomato, they died before entering the larval resting stage.

It was considered of importance to record those details, since quite large numbers of mites were able to complete their development when assembled upon comparatively small portions of carnation leaves which had been floating on water for periods of seven to 18 days prior to hatching of the eggs (and which incidentally had supported the life of five adult females during deposition of those eggs) so that the mites actually became mature when the leaves had been floating in all for from 15 to 31 days after they had been detached from the plant.

(6) Biological Notes

When a male mite was placed upon a leaf with a female in the deuteronymph resting stage, it soon took up a position beside or upon the latter until the ecdysis was about to take place. The male then suddenly became active, and paired with the female as it emerged from the nymphal skin. Seven pairs of mites were observed in the act of mating, which lasted for from two to six minutes. In no case was a female seen to be mated a second time during the course of its life. The first eggs laid both by mated and unmated females were deposited from one and a half to three and a half (with an average of two) days after the ecdysis from the deuteronymph stage.

Since the female mites laid, on the average, only some three or four eggs each in the course of 24 hours, the actual deposition of an egg was observed on very few occasions. The mite first laid down a few strands of webbing over a small area of the leaf-surface, attaching the ends of the threads to any slightly raised portion thereof. The mite then came to rest, and the egg was merely protruded from the genital opening in the course of little more than one minute. As soon as the egg was free from its body, the mite moved away to some distance and voided the contents of the hind-gut, in the form of a mucilaginous drop containing many granules of dark excrement, upon the leaf-surface: the drop dried up almost instantaneously.

The egg is almost perfectly spherical and the thin but tough transparent shell appears to be homogeneous.

Sections of the eggs cut in situ upon leaves of pansy show that they are not in actual contact at any point with the leaf-surface, and are separated from it to a distance of 15 to 60 μ by the strands of webbing.

It is probable that the eggshell is coated externally with a very thin layer of a slightly sticky secretion which causes it to adhere to the webbing.

After hatching from eggs laid upon floating carnation leaves in July and August, males took eight to 10 and females 10 to 12 days to reach maturity at mean temperatures of 70° F. to 71° F. (range 63–77° F.) and respectively 11 days and 12 to 14 days at 65° F. to 66° F. (range 62–71° F.).

(7) Effects of humidity upon viability of the Eggs

The great majority of eggs deposited upon portions of leaves or on cork discs, whether kept

subsequently in a moist chamber or under comparatively dry conditions when exposed to the air in the laboratory hatched with a period of incubation normal for prevailing temperatures. In May, a carnation leaf upon which 56 eggs had been deposited was divided into three approximately equal portions. One portion with 18 eggs was exposed to the air, and all but one hatched with an incubation period of six to nine days, a percentage viability of 94. Another portion with 12 eggs was kept in a covered moist chamber, and all hatched with an incubation period of six to eight days. The third portion with 26 eggs was placed in a dessicator over fresh calcium chloride: all but three of them hatched with an incubation period of six to 10 days, giving a percentage viability of 87.

The mean temperature prevailing over the period until the last egg hatched was 63° F. (range 58–66° F.). Since the average period of incubation for eggs at this temperature was found to be in the region of 10 days, the first eggs on each portion of the leaf hatched on the sixth day, and since seven out of the 26 eggs in the dessicator hatched upon the tenth day, the age of the eggs at the time at which they were subjected to the three different treatments can be estimated as from at most a few hours to a maximum of six days.

An egg which was seen to be deposited upon a portion of a cucumber leaf was transferred within 15 minutes to the dessicator: it hatched upon the ninth day, the mean temperature during incubation being 65° F. (range 62–72° F.).

In June, 15 eggs transferred to the dessicator within 24 hours of being deposited on a portion of cucumber leaf all hatched with an incubation period of six to 10 days (average seven days), the mean temperature during incubation being 66° F. (range 62–69° F.).

A small number of eggs which were removed upon the point of a needle from the leaf-surface upon which they had been laid to two cork discs, one of which was placed in the dessicator and the other in a moist chamber, collapsed within 24 hours: doubtless they had been injured in transference.

It had been noted that eggs deposited near the edge of a floating tomato leaflet over which the surrounding water had encroached, causing them to become submerged for considerable periods of time, hatched successfully after the leaf had been dried. In June, portions of a carnation leaf upon which 22 eggs had recently been deposited were submerged in distilled water, and kept submerged by pinning them to a thick layer of paraffin-wax with which the bottom of the watch-glass has been covered. An extensive layer of air which was retained in the meshes of the webbing upon which the eggs rested, was removed by means of a fine brush. After submergence for seven days, the portions of leaf were removed, allowed to dry, and placed in a moist chamber. Within one hour 14, and during the following two days, two more eggs collapsed. Of the remaining six eggs, three hatched subsequently, with an incubation period of nine to 12 days from the time at which they had been submerged.

Some eggs, and probably only those in which development had proceeded to a considerable extent, therefore retained their viability after submergence in water for a long period of time.

REFERENCE

CALLAN, E. MC. C., 1947, *Nature*, 160, p. 432.

2. SOME EFFECTS UPON RED SPIDER-MITE OF BIS-DIMETHYL AMINE PHOSPHONOUS ANHYDRIDE

The lethal effects of bis-dimethyl phosphonous anhydride, hereinafter referred to as "anhydride," upon the greenhouse Red Spider-mite were observed from simple experiments involving the use of Callan's flotation method described in *Nature* 160, p. 432, 1947.

The experiments with the anhydride were carried out in April and May, when mean temperatures recorded in the laboratory fluctuated between 60° F. and 64° F., with a range of 56° F. to 70° F. Whole tomato leaflets with approximate dimensions of 70 mm. length by 40 mm. greatest width or discs some 12 mm. in diameter cut out from leaflets were floated under-surface upwards upon a 0.1 per cent. solution of the anhydride either in water or in a standard nutrient solution containing 200 p.p.m. potassium as K_2O , contained in uncovered dishes. Cork discs, 12 to 20 mm. in diameter, with one surface and the perimeter covered with paraffin-wax, were also floated upon the solution with the unwaxed surface upwards. Similar leaflets and discs floated upon water or nutrient solution were used as controls.

Adult mites of the summer form were transferred to these objects from carnation plants upon

which they had been bred: the period of their survival and the number of eggs deposited by the females was recorded.

(a) Whole tomato leaflets

In a preliminary trial a leaflet upon which five female mites had been placed was floated upon nutrient solution containing anhydride. The average life of the mites was four days (range 3–4 days) and two eggs were deposited, both viable with an incubation period of 14 days. Of four males and 14 females introduced subsequently on to the leaf-surface, none of the former survived for more than 24 hours, and of the latter for more than 48 hours—in all three eggs were deposited, two of which were viable with an incubation period of eight days.

It thus became apparent that some two days elapsed before the leaf tissues absorbed the anhydride in sufficient quantity to cause death of the mites within a minimum period of time. In subsequent experiments the leaflets were therefore floated on the solution for two days before introduction of the mites.

(1) Controls. (a) On water: average life of males was 12 days (range 8–16 days), of five females 29 days (range 18–39 days). Eggs deposited 36 (average seven per female), all viable with incubation period of nine to 15 days. (b) On nutrient solution: a male survived for seven days, average life of four females 15 days (range 12–17 days). Eggs deposited seven (average two per female), five viable with incubation period of 11 to 13 days.

(2) Anhydride in aqueous solution. A male and five females survived for less than 20 hours; no eggs were deposited. After three days in all upon the solution, the leaflet was floated on water, and female mites introduced on to its surface at intervals during an ensuing period of 10 days. Of 21 females, none survived for a period of more than 48 hours, and no eggs were deposited.

(3) Anhydride in nutrient solution. Six females survived for less than 19 hours. Eggs deposited four, all viable with incubation period of 14 days.

After three days in all upon the solution, the leaflet was floated on nutrient solution, and female mites introduced on to its surface at intervals during an ensuing period of 10 days. Of a total of 20 mites, seven survived for less than 48 hours, and the remainder for from three to five days; in all five eggs were deposited, all of which were viable with an incubation period of eight to 14 days.

Flotation of the leaflets for two days upon the anhydride solutions sufficed to render their tissues poisonous to mites feeding upon them. Once absorbed into the leaf-tissues, the anhydride was retained within them in quantity sufficient to cause comparatively rapid death of mites for periods up to at least 10 days. In the controls, the mites survived for shorter periods and laid fewer eggs upon the leaflet floated on nutrient solution than on the leaflet floated on water. On the other hand, they survived for rather longer periods (and thus sufficient for some of them to deposit a few eggs) upon the leaflet which had absorbed both anhydride and nutrient solution than upon the leaflet which had absorbed only the anhydride and upon which no eggs were laid.

The observations would appear to indicate that the nutrient solution employed rendered the leaf-tissues distasteful to the mites, so that they fed sparingly and consequently took longer to ingest a lethal dose of the anhydride.

(b) Discs cut from tomato leaflets

(1) Controls. (a) On water: eight females were alive and active after 10 days, and deposited 18 eggs within that period. (b) On nutrient solution: average life of four females was nine days (range 6–14 days). Eggs deposited 10 (average 2.5 per female), all viable with incubation period of 12 to 15 days.

(2) Anhydride in aqueous solution painted with brush on to under-surface, on which mites were subsequently placed, and allowed to dry; disc floated on water. During the first six days, 13 females placed on the disc (at the rate of two to three daily) survived for less than 17 hours; in all, three eggs were deposited. Three females placed on the disc upon the eighth day survived for two to three days and deposited in all five eggs; four females introduced upon the seventeenth day survived for three to four days and laid in all nine eggs.

All the eggs deposited were viable with an incubation period of 10 to 14 days.

(3) Anhydride in nutrient solution, disc floated on solution. Five females survived for less than 24 hours and deposited no eggs. During the ensuing four days, eight females survived for less than 19 hours and laid no eggs.

There was some indication that the anhydride, after absorption by the leaf-tissues, persisted in them, and was only partially extracted after flotation of the discs upon the water for at least seven days. Confined to a small area, the mites were not deterred from feeding upon tissues which had absorbed nutrient solution.

(c) Cork discs

(1) Control on water. Average life of five males was 12 days (range 7–15 days), of five females 13 days (range 10–16 days); eggs deposited seven, six of which were viable with incubation period of 10 to 13 days.

(2) Anhydride in aqueous solution. (a) Disc floated on solution: Of two males, one survived for less than 24, and one for between 24 and 48 hours; of 16 females, four survived for less than 24, three for between 24 and 48, seven for between 48 and 72, and two for between 72 and 96 hours; eggs deposited four, of which three were viable with incubation period of 13 days.

(b) Solution painted on surface of disc with brush, allowed to dry, and disc floated on water. Three females survived respectively for between 24 and 48, between 48 and 72 hours and between five and six days; eggs deposited seven, all of which were viable with incubation period of 12 to 14 days.

(3) Anhydride in nutrient solution. Two males and six females survived for between 24 and 48 hours; eggs deposited two, incubation period not recorded.

The results obtained showed that the anhydride solutions when imbibed by the mites were directly toxic to them; the very small quantity which could have been injected by them from a cork surface to which the solution had been applied was sufficient to cause death. It was noted that the mites which survived for the longer periods were those which were frequently found to be floating upon the solutions and had to be returned to the cork surface from time to time.

In this connection, mites were totally immersed for periods of from 30 minutes to three hours in the anhydride solution. Of six males and six females so treated, all regained their activities after transference to a tomato leaflet floated upon water, but all except one female subsequently died within periods of from less than 16 hours to a maximum of 48 hours. This female survived for four days and laid two eggs, one of which was viable with an incubation period of 12 days. Four males placed upon the leaflet after death of the female survived for an average period of nine days (range 6–12 days).

It was concluded that the anhydride was probably not absorbed through the cuticle of the mite, but gained access to the internal organs partly from small quantities injected through the mouth and perhaps through the genital orifice of the female during submersion.

Summary

Mites kept upon tomato leaflets or portions of them which had absorbed anhydride from a 0.1 per cent. solution either in water or in nutrient solution remained alive for much shorter periods of time and were consequently able to deposit far fewer eggs than mites kept upon similar objects floated upon water or nutrient solution. Flotation for long periods of time upon water did not entirely remove the anhydride from the leaf-tissues once it had been absorbed by them. The viability of eggs laid by the mite upon leaflets which had absorbed the anhydride, or upon a cork surface to which it had been applied, was not impaired, nor was the period of their incubation affected. Solutions containing 0.1 per cent. anhydride were directly toxic to mites which imbibed them; there was no evidence that they had any true contact action upon the mites.

3. TOMATO LEAF-MINER (*Liriomyza solani* Her)

1. Biological Notes

In January, young cucumber pot-plants, the foliage of which contained larvæ of a Leaf-miner, were received from a newly-erected glasshouse at Waltham Abbey, Essex; larval mines also occurred in the foliage of tomato seedlings grown in the same house.

Six larvæ in the cucumber leaves vacated their mines in order to pupate between January 24th and 26th, and the adult flies (three males and three females) emerged from the puparia, which had been kept at a mean temperature of 65° F. on February 12th and 13th. The adult flies appeared to be structurally inseparable from the species *L. solani* Her., and two of the females which were kept

under lampglasses placed over young tomato plants made feeding pits, and after mating with the males, laid eggs in the secondary leaves. Many larvæ which hatched from these eggs mined in the tomato leaves and were reared to maturity, thus proving beyond doubt that this particular leaf-miner is polyphagous, and is not confined to Solanaceous plants.

The two pairs of flies were kept under close observation and were transferred every three days to a fresh tomato seedling, bearing no cotyledons and from four to six expanded secondary leaves, until their span of life was ended, one pair being provided with syrup as an additional source of food and the other pair not so provided.

In the glasshouse in which the first two plants provided for each pair were kept, the mean temperature for the three-day periods lay between 61° F. and 63° F. and in both cases the females deposited but few eggs: subsequently the plants were kept in another glasshouse in which the mean temperatures were 67 to 68° F.

The male fly provided with syrup lived for 14 days, and the one without additional food for eight days. The latter male was actually observed to mate with the female, and remained *in coitu* with it for a period of 36 minutes. A second male introduced after death of the first was not seen to pair with the female.

The female provided with additional food survived for 20 days and laid the first egg seven days after it had emerged from the puparium: it deposited in all some 70 eggs, 68 of which were viable, the greatest number (27) being laid upon the fourth plant provided, during the seventh to ninth day after oviposition started. The average number of eggs deposited daily over the 14-day period of oviposition was five, with a maximum of nine.

The female not provided with additional food survived for 13 days, and laid the first egg four days after it had emerged from the puparium and within 24 hours of pairing with the male: it deposited in all some 30 eggs, 28 of which were viable, the greatest number (21) being laid upon the second and third plants provided, during the second to sixth days after oviposition started. The average number of eggs deposited daily over the nine-day period of oviposition was three with a maximum of four.

Both females made feeding pits upon the foliage before they had paired with the males. From Table V, in which the distribution of the feeding pits and eggs in the foliage of the plants provided for both flies together is given, it is apparent that, whereas the greatest amount of feeding took place upon the two lowest leaves, the greatest number of eggs were deposited in the two leaves above these. It should be recalled that each egg is deposited in a separate pit similar to that made solely for the purpose of feeding.

TABLE V

Liriomyza solani Her.DISTRIBUTION OF FEEDING-PITS AND EGGS IN
FOLIAGE OF YOUNG TOMATO PLANTS

No. Plants	Leaf	Feeding-pits				Eggs
		Very many	Many	Few	None	
9	Lowest	6	2	1	0	6
9	2nd	3	4	2	0	7
9	3rd	2	1	5	1	33
8	4th	2	0	5	1	34
7	5th	0	0	1	6	16
2	6th	0	0	0	2	0

At mean temperatures of 61 to 65° F. (range 56–84° F.) the observed incubation period of 10 eggs was seven to eight days, and of 67 to 69° F. (range 56–87° F.) that of 80 eggs was five to six days.

At a mean temperature of 68° F. (range 56–87° F.) larval development occupied a period of nine to 14 days, with an average of 11 days.

By surrounding each plant with an inverted paper cone containing moist cotton-wool in its lower end, at a time when the larvæ began to vacate their mines in order to pupate, 59 puparia were obtained, but this does not represent the full compliment of larvæ which completed their development. Only two larvæ were observed to form the puparium within the larval mine.

2. Development within the Puparium

As they vacated their mines in the tomato plants, the full-fed larvæ, which were the progeny of two female flies of similar origin and which had been reared under similar conditions, were transferred to moist blotting paper, and as soon as the integument had hardened and become of a yellow or brown colour the puparia were placed upon a wad of either moist or dry cotton wool contained in glass vials covered with muslin.

Some puparia were kept in the laboratory at a mean temperature of 64° F. (range 59–69° F.), some in an incubator at a constant temperature of 80° F. and others in a refrigerator at 35° F. In addition, a number were kept in the laboratory for periods of two to six days before subjection to the higher and lower temperatures respectively. The puparia were obtained between March 8th and 20th. On July 4th, i.e. 15 to 17 weeks after their formation, those from which flies had not emerged in the laboratory and incubator were dissected, while those in the refrigerator were transferred to the incubator at 80° F.; the latter puparia, from which no flies emerged, were dissected on August 27th, i.e. seven to eight weeks after their transference to the higher temperature.

The following results were obtained:—

At 64° F. (range 59–69° F.):

- (a) Ten puparia on moist wool: Seven flies (three males, four females) emerged, 76 to 119 (average 91) days after formation of the puparia. Three unemerged puparia had died before or shortly after ecdysis to the pupal instar.
- (b) Ten puparia on dry wool: One female fly emerged on sixty-third day after formation of the puparium. Nine unemerged puparia contained a living pupa, four males and two female flies dead and fully sclerotised, two dead pupæ, with short wing and leg cases.

At 80° F.:

- (a) On moist wool: Eight newly-formed puparia; one male fly emerged on tenth day after formation of the puparium. Seven unemerged puparia; one contained a dead fully sclerotised female and one a dead partially sclerotised fly; five had died before or shortly after ecdysis to the pupal instar.
One puparium, three days after formation, contained a dead fully sclerotised male fly.
One puparium, five days after formation; female fly emerged on twelfth day after formation of the puparium.
Under these conditions of temperature and humidity the puparia became overgrown with dark moulds and their shells tended to become soft.
- (b) On dry wool: Eight newly-formed puparia; no flies emerged. One contained a dead fully sclerotised female fly, the remainder had died before or shortly after ecdysis to the pupal instar.
Two puparia, three days after formation, contained dead fully sclerotised flies (one of each sex).

At 35° F. for 15–17 weeks, subsequently at 80° F.

- (a) On moist wool: Seven newly-formed puparia; died before ecdysis to the pupal instar.
One puparium, four days after formation, alive after 16 weeks in the refrigerator.
- (b) On dry wool: Two newly-formed puparia; died before ecdysis to the pupal instar.
Seven puparia, two to six days after formation; no flies emerged; each contained a dead fully sclerotised fly (five males, two females).

Puparia which contained large numbers of calcosphaerites, in which the soft tissues had disintegrated and the larval mouth parts had not become embedded in the wall of the emergence cap, were deemed to have died before ecdysis to the pupal instar.

In the majority of the many instances in which the fly had developed to maturity but died within the puparium, the pupal skin enveloping it was open at the anterior end, and only the head of the insect projected through the orifice, the fully sclerotised legs and wings being contained within their cases: the emergence cap of the puparium remained firmly closed. It would appear probable that both aridity and comparatively high temperatures tend to prevent opening of the cap, which is evidently brought about by external influences. In the case of flies which emerged successfully, a period of at least 24 hours elapsed before they became fully sclerotised.

From these observations it was concluded that the conditions most favourable for successful development within and emergence of flies from the puparia were a moderate temperature and

humid surroundings, conditions which are consistent with the habits of an insect the larvæ of which usually pupate beneath the soil-surface.

At a constant temperature of 80° F. a large proportion of newly-formed puparia succumbed before appreciable development had proceeded within them; development in the few which survived was abnormally rapid.

Newly-formed puparia did not tolerate a temperature of 35° F., but puparia in which ecdysis to the pupal instar had been completed, survived for a period of at least 17 weeks at this temperature, and development to maturity was effected subsequently when they were kept at 80° F. These conclusions are to some extent borne out by other records.

Six puparia obtained between February 24th and 26th from larvæ mining in cucumber plants were kept upon moist wool in a heated glasshouse in which the mean temperature recorded was 65.2° F. (range 58–80° F.). From all of these the flies, three males and three females, emerged eighteen to nineteen days after their formation.

Eight puparia obtained between March 1st and 4th from larvæ mining in tomato plants from Sussex were placed upon moist wool and kept in a heated glasshouse in which the mean temperature recorded was 67.5° F. (range 46–102° F.). During the periods of high temperature it was not found possible to keep the wool moist. Flies emerged from only four of these, a male on the nineteenth and a male and two females between the forty-second and sixty-seventh day after formation of the puparia. Of the four unemerged puparia dissected 18 weeks after their formation, one, with the emergence cap open, contained a dead partially sclerotised female fly, and the others each a pupa which had died at an advanced stage of development.

In this case the developing pupa had evidently been unable to tolerate the periods of high temperature under arid conditions.

Some doubt now arises as to whether it is justifiable either to compute the duration of the pupal instar from the time which elapses between the formation of the puparium and emergence of the adult fly from it, or to assume that a state of diapause is ever entered in this instar.

4. INSECTICIDES

(a) Laboratory Investigations

By W. H. READ and R. J. SMITH

Acaricides

The search for alternatives to azobenzene and parathion for the control of the glasshouse Red Spider mite (*Tetranychus telarius* L.) has been continued and the ovicidal properties of many compounds have been determined. The leaf-disc dipping technique, used in previous years, has been employed without modification.

Further investigation of the ovicidal activities of chlorine substituted phenyl benzenesulphonates by this technique confirmed last year's results since 4-chlorophenyl benzenesulphonate was again found more ovicidal than 4-chlorophenyl 4-chlorobenzenesulphonate, the active principle in the acaricide (K6451) which has given promising results in America. Substitution of chlorine in the benzenesulphonate group appeared to reduce the toxicity of compounds containing chlorine in the phenyl group. The ovicidal activity of 2 : 4-dichlorophenyl benzenesulphonate was approximately equal to that of 4-chlorophenyl 4-chlorobenzenesulphonate, whereas the 2 : 4-dichlorophenyl 2 : 4-dichlorobenzenesulphonate was not appreciably toxic and the phenyl 2 : 4-dichlorobenzene-sulphonate was only slightly toxic.

None of the chlorine substituted phenyl benzenesulphonates are as toxic as azobenzene to eggs of the glasshouse Red Spider mite when assayed by the leaf-disc dipping technique. The mechanism of ovicidal action of these compounds when applied to plants may be such that assays with leaf-discs are unsatisfactory, however, since at least some of these compounds, or products derived therefrom, are able to exert a toxic effect on eggs on the undersides of leaves when applied to upper leaf surfaces only.

The heterogeneity of departure from fitted probit-regression lines calculated from the results obtained with chlorine substituted phenyl benzenesulphonates by the leaf-disc assay method, as

shown by the highly significant values for χ^2 , may be due to the unsatisfactory nature of the technique when used for determining the ovicidal potencies of compounds of this type.

Further investigations of the acaricidal properties of the phenyl benzenesulphonates are necessary to determine their relative potencies, mechanism of action and phytotoxicities.

The ovicidal properties of series of anils, oximes, and phenylhydrazones, containing chlorine in one or two phenyl groups, have been investigated and a detailed account of this work will be given elsewhere.

(b) Red Spider Mite Control in Glasshouses

Limited quantities of the most acaricidal chlorinated phenyl benzenesulphonates were available for testing against Red Spider mites in glasshouse trials.

Trials with 4-chlorophenyl benzenesulphonate (PCPBS) and the 2 : 4- and 4 : 4'-dichloro analogues showed that all are injurious to cucumbers when applied as aerosols or conventional sprays at concentrations necessary to obtain satisfactory control of the glasshouse Red Spider mite. Since the problem of Red Spider control is most acute in respect of cucumbers, the potential value of the chlorinated phenyl benzenesulphonates is reduced on this account. No information is available from tests at Cheshunt regarding the tolerance of plants other than cucumbers and tomatoes, to these compounds.

A further disadvantage of the chlorinated phenyl benzenesulphonates is their slow action on adult mites. The somewhat inconsistent results obtained in trials with these compounds may be due to the movement of adult mites to leaves which expanded after plants had been treated and which may have been inadequately protected by the acaricide. This is a possible explanation of the inferior control obtained on young cucumber plants than on young tomato plants in certain of the trials.

For example, the application of 3g/1,000 cu. ft. of 4-chlorobenzenesulphonate as an aerosol by dispersing a 20 per cent. solution with a paint spray gun gave a mortality of 96 per cent. of eggs present at the time of treatment on cucumbers and 59 per cent. on tomatoes. Newly hatched larvæ were killed over a period of 10 days on both species of plants. After a period of five weeks, however, the cucumber plants were much more heavily infested than the tomato plants grown in the same glasshouse.

Further tests showed that dosages of 2.5 g/1,000 cu. ft. of the 4 : 4'-dichloro compound gave almost complete control of young stages of mites by virtue of ovicidal action and residual toxicity to newly-hatched larvæ but that adult mites survived and laid viable eggs.

Preliminary glasshouse trials with 4-chlorophenyl benzenesulphonate (PCPBS) gave very promising results on established tomato plants but in one test a dosage of 3g/1,000 cu. ft. dispersed as an aerosol from a 20 per cent. solution in acetone, by compressed air spraying, injured young tomato plants. Almost complete control of mites was obtained with 4g/1,000 cu. ft. in trials during warm weather. Later in the season variable results were obtained and it is possible that this was due to the slow development of the mites due to abnormally cool weather.

2 : 4-dichlorophenyl benzenesulphonate was available in sufficient quantity for only one test as an aerosol in a glasshouse. The dosage employed was 3g/1,000 cu. ft. and examination of the plants showed that the kill of eggs was 91 per cent., but the residual effect appeared less pronounced than with the 4-chloro and 4 : 4'-dichloro compounds since larvæ which hatched four days after the plants were treated survived and developed into adult mites.

Systemic Insecticides

Further experiments on the control of Red Spider mites and aphids on carnations have shown that these pests can be controlled on young plants making rapid growth in the spring and summer, by applying certain systemic insecticides to the soil or by spraying the plants with such insecticides. The application of the same insecticides to the soil gives unsatisfactory results on older, flowering carnations, particularly in the late autumn and winter.

Control of fern mite (*Tarsonemus tepidariorum*) and the aspidistra scale (*Chionaspis aspidistræ*) on *Asplenium* spp. and *Nephrolepis* sp. respectively, have been obtained by watering the plants with 0.2 per cent. solutions of a proprietary systemic insecticide said to contain approximately equal amounts of schradan and the higher homologue triphosphoric penta (dimethylamide) as the active, systemic insecticides.

IV. CHEMICAL INVESTIGATIONS

I. THE PROPERTIES OF SOME UREA-FORMALDEHYDE MATERIALS IN RELATION TO THEIR POSSIBLE USE AS NITROGENOUS FERTILIZERS

By G. W. WINSOR and M. I. E. LONG

In the Annual Report for 1950 a brief account of the known properties of urea-formaldehyde compounds was given in relation to their possible use as nitrogenous fertilizers. The main interest of such materials lies in the possibility of preparing synthetic fertilizers of standardised properties to supplement or even replace the natural organic fertilizers such as hoof and horn. The value of these natural organic materials is well established by their continued use over many years. Being obtained, however, from various sources throughout the world and processed in a variety of ways, these natural products, though of guaranteed nitrogen content, vary considerably in their rates of decomposition in the soil. The development of suitable synthetic organic materials would offer the possibility of greater uniformity of product. Of still further interest would be a range of graded products having different rates of decomposition in the soil; the fertilizer could thus be selected to suit the particular crop and its conditions of growth.

As previously reported in 1950, the main contributions to our knowledge of urea-formaldehyde products as possible nitrogenous fertilizers have undoubtedly been those from the Bureau of Plant Industry at Beltsville, U.S.A. In a preliminary paper on this subject Yee and Love (1946) ¹ reported nitrification tests made on a range of urea-formaldehyde products, some of which gave results of considerable promise. Further publications from Beltsville have added considerably to our knowledge of the reaction between urea and formaldehyde and of methods of testing the products in the laboratory.^{2, 3, 4} Urea-formaldehyde materials prepared by these workers are still being tested in the field at Beltsville and at other centres. The full results of these vegetative trials are still awaited, though the results at present available include successful trials with turf grasses.⁵ It is of interest to note, however, that neither the investigation of reactions between urea and formaldehyde nor the suggested use of the reaction products as slow-acting nitrogenous fertilizers are very recent developments. A patent ⁶ for the production of a gradually available fertilizer by interaction of urea and formaldehyde in the presence of an organic carrier such as peat was granted before the war. Use of the interaction of urea and formaldehyde was also made in a material referred to as urea-ammonia liquor-37, developed in America for use in mixed fertilizers. As far as is known, urea-formaldehyde compounds suitable for use as nitrogenous fertilizers are not as yet commercially available in this country, though patents for their production have been granted in America ⁷ and France.⁸ In view of their possible importance in horticulture a range of samples has therefore been prepared in these laboratories.

The reactions between urea and formaldehyde are undoubtedly of very considerable complexity. Factors influencing the nature of the products include the ratio of urea to formaldehyde, expressed in gram-molecules of the two substances and subsequently referred to as the U/F ratio, and the pH, temperature, and time of reaction. Since the reacted mixtures contain substances of varying solubility, the methods used in the isolation of the products greatly effect their resulting properties. The possibility of continued interaction during drying of the products introduces further complicating factors. The number of variables involved is thus considerable; to eliminate one such factor all preparations were commenced at a pH of 3.5. Considerable attention has, however, been given to the effect of U/F ratio on the properties of the products obtained by each method of preparation.

A more complete account of this work, including details of the experimental methods, will be published elsewhere. The experiments on the mineralization of nitrogen in the soil were made at a concentration of 300 p.p.m. added nitrogen at a constant temperature of 23.5° C.

Results obtained from Various Methods of Preparation

METHOD A

The first series of urea-formaldehyde materials in the present work was prepared as follows: 100 g. urea were dissolved in 128 mls. of a solution of formaldehyde containing sufficient of the latter to give the desired molar ratio of urea to formaldehyde (U/F ratio). When used without

dilution, 128 mls. of the stock formalin gave a U/F ratio of 1 in the reactants. For higher U/F ratios the formalin was diluted with water to maintain a constant volume throughout the series. The reaction mixture was brought to 30° C., and the pH adjusted to 3.5 with N/10 phosphoric acid. The temperature then rose spontaneously and precipitation occurred, the mixture being stirred mechanically throughout. When the temperature began to fall the mixture was heated to 90° C. and maintained at that level for 20 minutes. The resulting product, a semi-solid paste, was dried at 90° C. for 18 hours, broken up and passed through a 40-mesh sieve.

Using this method, eight samples were prepared from reaction mixtures of U/F ratio 1 to 3. The content of total nitrogen in these samples is given in Table I, together with the percentage of this nitrogen present as urea and as water-soluble nitrogen.

TABLE I
UREA-FORMALDEHYDE MATERIALS PREPARED BY METHOD A WITH VARIOUS RATIOS OF REACTANTS

Sample No.	U/F Ratio of Reactants	Total Nitrogen %	Soluble Nitrogen*	Urea-Nitrogen*	Mineralization in Soil† %
17	1.0	35.01	0.4	0.3	—
18	1.2	38.51	8.4	4.1	11.7
19	1.4	39.51	18.3	10.6	38.6
20	1.6	40.40	37.1	15.4	61.5
21	1.8	40.93	48.9	20.5	65.2
22	2.0	41.38	65.7	27.8	76.6
23	2.5	42.43	80.2	36.6	82.9
24	3.0	43.16	89.2	45.0	83.1

* Soluble nitrogen and urea-nitrogen both expressed as a percentage of the total nitrogen.

† Mean values after incubation in soil for 104 and 135 days.

The total nitrogen content of the samples increased with the U/F ratio of the reactants over the range 35 to 43 per cent. The highest values are doubtless due in part to the increased content of unreacted urea (46.66 per cent nitrogen), though even after removal of the water-soluble constituents the nitrogen content shows some increase with U/F ratio. The percentages of this total nitrogen soluble in water showed a very wide range, increasing with U/F ratio from 0.4 to 89.2 per cent. About half of this soluble nitrogen was present as free urea, as determined with urease. Thus at high U/F ratios the reaction is far from complete with regard to urea.

The samples referred to in Table I were tested in the laboratory for rates of decomposition in the soil, analyses for ammonia and nitrate being made periodically throughout an incubation period of 135 days. For purposes of comparison with a known fertilizer an additional series of determinations was made with a fine sample of calcined hoof and horn. Values for the sum of ammonia and nitrate nitrogen formed, expressed as a percentage of the total nitrogen added, are plotted against period of incubation in days in Fig. 1; sample 17 was practically inert in the soil and has been omitted from the graph. These values, subsequently referred to as percentages mineralized, show a steady increase with the U/F ratio of the reactants at any one sampling date. There is definite evidence for a break in the curves in each case between three and six days. On plotting the mean values for percentage mineralized at three and six days for each U/F ratio against the percentage of nitrogen present as free urea (Table I), a very close relationship is obtained, as in Fig. 2. There is thus little doubt that this initial mineralization of nitrogen depends on the amount of free urea in the sample. Between the tenth and fourteenth days there is evidence for a second break in some of the curves. This coincides with the time at which ammonia which had accumulated in the early stages was reduced to a low level by nitrification. For samples 19 to 24, in which more than 10 per cent. mineralization had occurred at that time, the mean values for mineralization at 10 and 14 days amounted to 71 to 78 per cent. of the total soluble nitrogen. The second break in the curves may thus be attributed to approaching exhaustion of supplies of initially soluble nitrogenous constituents. Evidence of considerable lag before the insoluble constituents of these urea-formaldehyde samples were decomposed at appreciable rates will be given in a later section. To avoid undue compression of the data, the results shown in Fig. 1 refer only to the first 76 days of incubation; the tests were actually continued up to 135 days. Mean values for percentage mineralization at the last two sampling dates have therefore been included in Table I. From these results and those in Fig. 1 it is clear that urea-formaldehyde products can be prepared having widely

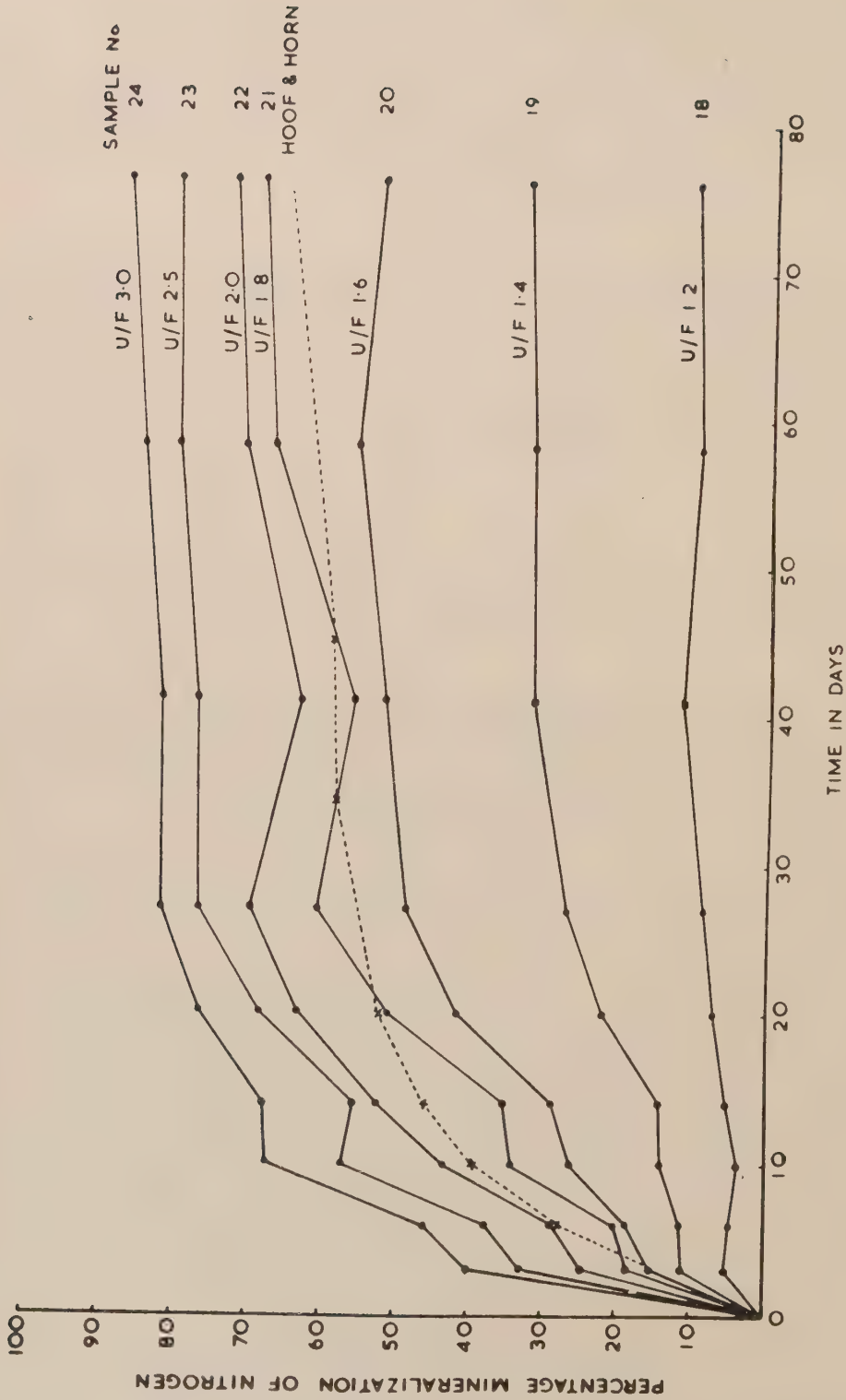


Fig. 1

Mineralization in soil of the nitrogen of urea-formaldehyde materials prepared at different U/F ratios by method A. For comparison a sample of calcined hoof and horn is shown by broken lines.

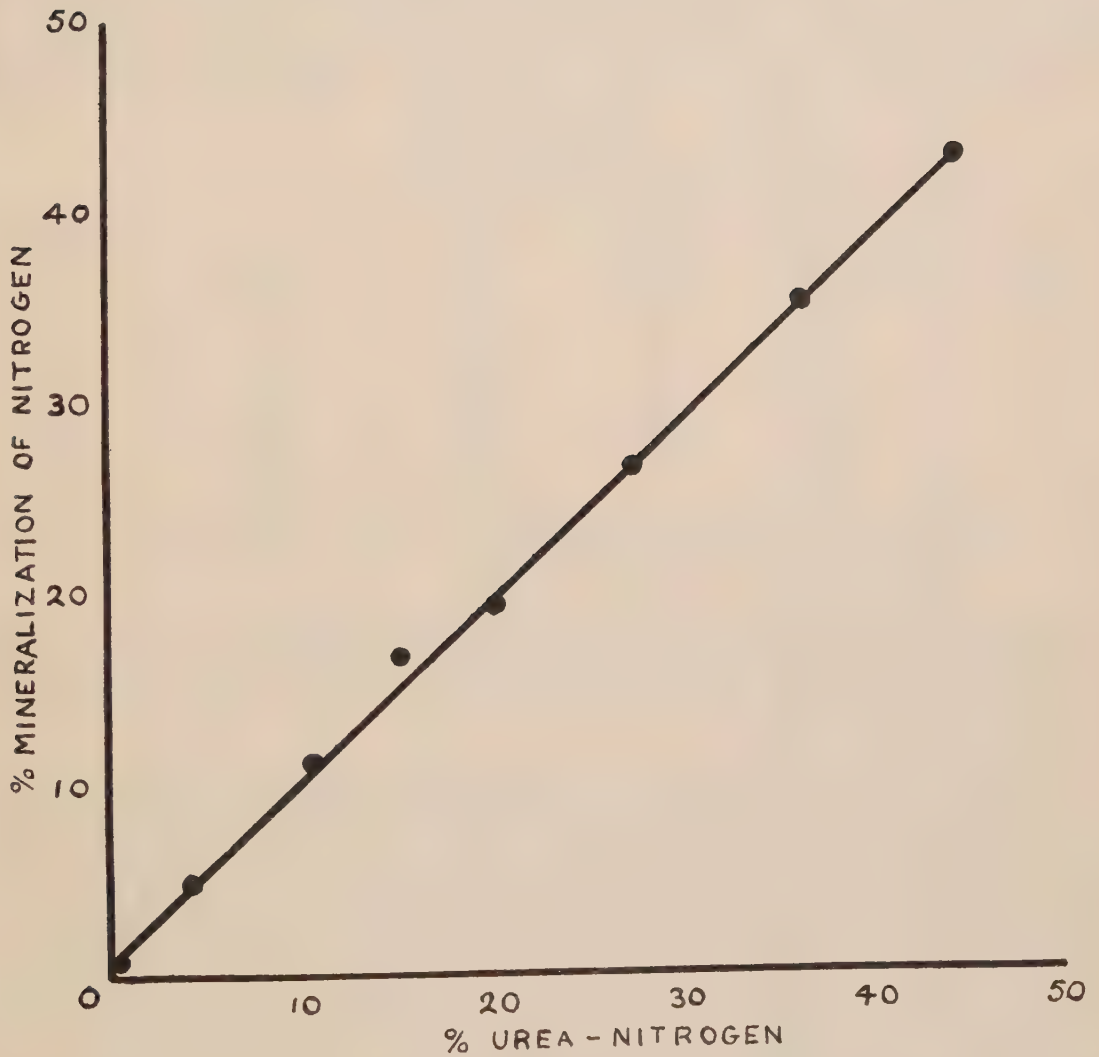


Fig. 2

Mean values for percentage mineralization of urea-formaldehyde samples prepared by method A, after incubation in the soil for three and six days, plotted against the percentage of the total nitrogen of the sample present as free urea.

different characteristics with regard to rate and extent of decomposition in the soil. These two properties appear, however, to be closely related in the present series, high availability in the soil being found only with high values for water-soluble nitrogen. Decomposition of sample 21, containing 48.9 per cent. of its nitrogen in water-soluble form, showed considerable similarity to that of fine hoof and horn in this test.

From the urea-formaldehyde samples prepared by method A a further series of washed samples was prepared. 20 g. samples of urea-formaldehyde material were shaken for one hour with 250 mls. of water and washed on Buchner funnels with a further 250 mls. after which the insoluble matter was dried overnight at 90° C. As expected from the soluble nitrogen content of the original samples (Table I), the recovery of insoluble nitrogen in the washed products decreased rapidly with increasing U/F ratio, as shown in Table II. The percentage of nitrogen in the washed products

TABLE II
UREA-FORMALDEHYDE MATERIALS, PREPARED BY METHOD A, AFTER EXTRACTION OF
SOLUBLE CONSTITUENTS WITH WATER.

Sample No.	U/F Ratio of Reactants	U/F Ratio of Products	Total Nitrogen %	Recovery of Nitrogen*	Mineralization in Soil† %
17	1.0	1.01	37.68	96.2	0.4
18	1.2	1.22	38.68	89.4	5.7
19	1.4	1.29	39.72	80.6	23.6
20	1.6	1.29	38.58	62.9	41.3
21	1.8	1.32	38.42	52.6	48.9
22	2.0	1.34	39.32	38.6	47.2
23	2.5	1.40	39.66	27.2	63.2
24	3.0	1.45	39.99	18.9	74.1

* Nitrogen in the extracted product as a percentage of the nitrogen in the original sample.

† Mean values after incubation in soil for 104 and 124 days. (For sample 24, 75 and 124 days.)

was in general less than in the unwashed materials, the differences being most marked at the higher U/F ratios. Analysis showed that the U/F ratio of the products increased with that of the initial reaction mixtures, but that the actual range of values for the products was much less than for the reactants. Thus increasing the initial U/F ratio from 1.0 to 3.0 only changed the ratio in the insoluble products from 1.01 to 1.45.

The washed products referred to in Table II were tested for rates of mineralization in the soil as previously described. In the absence of soluble nitrogenous constituents there was no tendency for ammonia to accumulate in the early stages, and hence only the combined values for ammonia and nitrate are reported. These values, expressed as a percentage of the total nitrogen added to the soil, are plotted against time for the first 75 days in Fig. 3. The experiment was continued up to 124 days incubation, and mean values for percentage mineralization of nitrogen at the last two sampling dates are included in Table II. The period of inactivity before maximum rates of mineralization were attained is clearly shown in the graph. Comparison of Figs. 1 and 3 supports the view that the increased rates of mineralization of the unwashed samples after 10 to 14 days' incubation are due to rapid decomposition of the initially insoluble constituents, at a time when the concentration of soluble organic nitrogen had already been considerably reduced. The availability of the nitrogen of these washed products in general increased with their U/F ratios, with the exception of the curves for samples 21 and 22 which intersected after 19 days' incubation. The maximum percentage mineralization of the added nitrogen was 74.2 per cent. for sample 24, a relatively high value for an initially insoluble material and higher than the corresponding figure for hoof and horn (Fig. 1).

Urea-formaldehyde Samples prepared by Method B

The products described in the earlier sections of this report appear to contain a considerable proportion of unavailable nitrogen, except at high U/F ratios corresponding to low yields in the preparation. In an attempt to produce samples of greater availability in the soil a further series of preparations was made under modified conditions. The main differences from the procedure previously described were in the use of lower temperatures for reaction and drying, and the drop-wise addition of the formaldehyde solutions:—

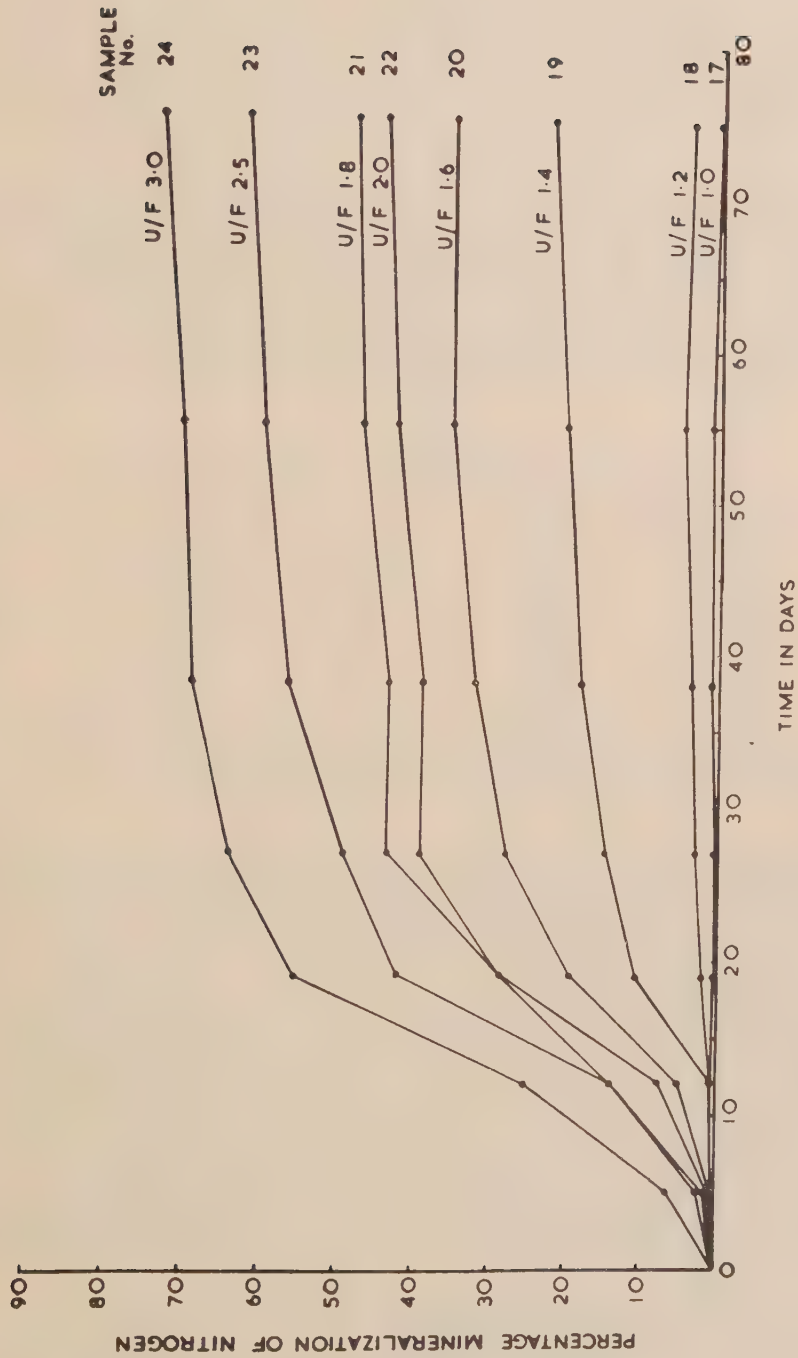


Fig. 3

Mineralization in soil of the nitrogen of urea-formaldehyde samples prepared by method A, but subsequently washed with water to remove soluble constituents.

METHOD B

100 g. urea were dissolved in 200 mls. of water and the solution adjusted to pH 3.5 with N/10 phosphoric acid. The temperature of the solution was then raised to 50° C. and the required amount of formaldehyde run in dropwise with constant stirring. The amounts of formalin calculated to give the required U/F ratios were in each case diluted to a constant volume of 128 mls., this being the volume of formalin required without dilution for a U/F ratio of 1. Addition of the formaldehyde solution took 30 minutes, and stirring was continued for a further 20 minutes. The mixture was then left at approximately 40° C. for 24 hours, after which it was filtered under reduced pressure and the products washed twice on the funnel with small quantities of water. The materials were then spread out to dry at 25° C. for 40 hours, and finally at 50° C. for two hours.

Analytical data for products prepared in this way are given in Table III. Both free urea-nitrogen and water-soluble nitrogen, expressed as a percentage of the total nitrogen, increased with the U/F ratio of the reactants. Separation of the products from the reaction mixture by filtration and subsequent washing on the filter still left appreciable amounts of soluble nitrogenous compounds in the preparations. The percentage recovery in the products of the nitrogen initially present in the reaction mixture decreased with increasing U/F ratio. This may be attributed to the greater solubility of the products and less complete reaction of the urea at high U/F ratios. Products prepared as described by dropwise addition of formaldehyde differed in form from the earlier preparations, the particles tending to settle out readily from the reaction mixture and being gritty to the touch.

TABLE III
UREA-FORMALDEHYDE MATERIALS PREPARED BY METHOD B

Sample No.	U/F Ratio of Reactants	Total Nitrogen %	Soluble Nitrogen*	Urea-Nitrogen*	Yield†
33	1.2	38.06	0.8	0.3	95.5
37	1.4	37.72	4.1	2.0	84.1
34	1.6	39.55	9.3	5.4	79.7
35	1.8	40.23	15.9	8.2	69.0
36	2.0	40.10	18.9	8.3	60.2

* Soluble nitrogen and urea-nitrogen expressed as a percentage of the total nitrogen.

† Percentage of the original urea-nitrogen recovered in the products.

Samples 33 to 37, described in Table III, were tested for rate and extent of mineralization in the soil under the conditions previously described. Samples 18 and 22, prepared by method A, were also included in the soil tests for purposes of comparison. The results are shown graphically in Fig. 4, in which the percentage conversion of the added nitrogen to inorganic forms is plotted against time in days. The percentage mineralization of the nitrogen of samples 33 to 37, prepared by method B, increased regularly with the U/F ratio of the reactants. The mineralization curves for samples 34 to 36 show two distinct stages which may be attributed to decomposition of the soluble and the initially insoluble portion of the samples respectively. Comparison of the results in Fig. 4 for samples prepared by methods A and B shows that in both cases higher availability in the soil was obtained by the former method. The differences in percentage mineralization of the nitrogen of samples 18 and 33, prepared with an initial U/F ratio of 1.2 in the reaction mixtures, may be attributed to the different amounts of water-soluble nitrogen present. At an initial U/F ratio of 2, however, the differences in degree of mineralization of the nitrogen of samples 22 and 36 were far less than might be expected from their content of water-soluble nitrogen as shown in Tables I and III. There is thus some indication that greater availability of the initially insoluble constituents was obtained by method B at the higher U/F ratios. The relative merits of urea-formaldehyde materials prepared by different methods are further discussed in a later section.

Urea-formaldehyde Samples prepared by Method C

In an attempt to increase the availability in soil of the initially insoluble constituents of urea-formaldehyde samples, further experiments were made at still lower temperatures. Preparations at 25° C. were first attempted in a constant temperature cabinet, without stirring. It was found, however, that the temperature rose spontaneously during reaction to above 30° C. and subsequent experiments were made in a water-thermostat. The details of procedure were as follows:—

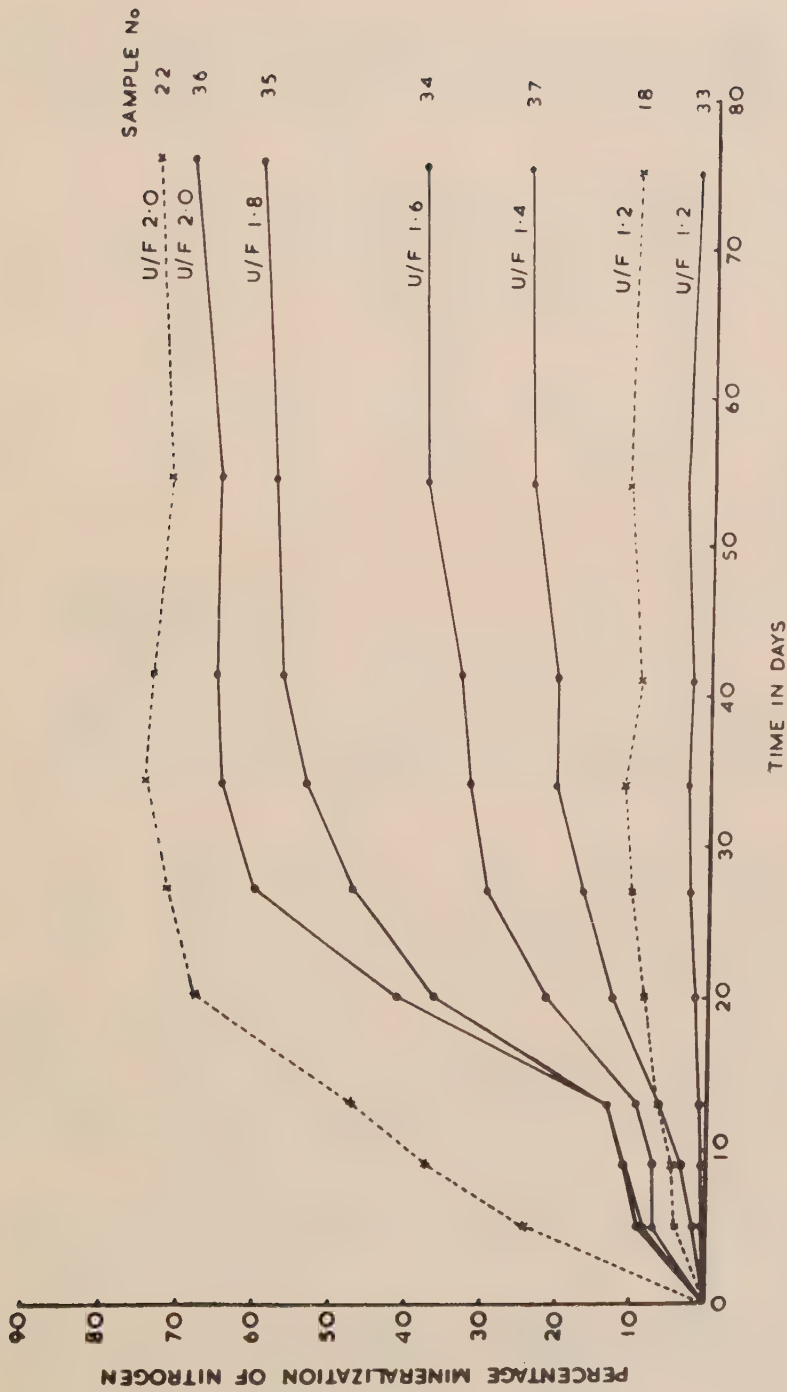


Fig. 4

Mineralization in soil of the nitrogen of urea-formaldehyde samples prepared by method B. For comparison, two samples prepared by method A are shown by broken lines.

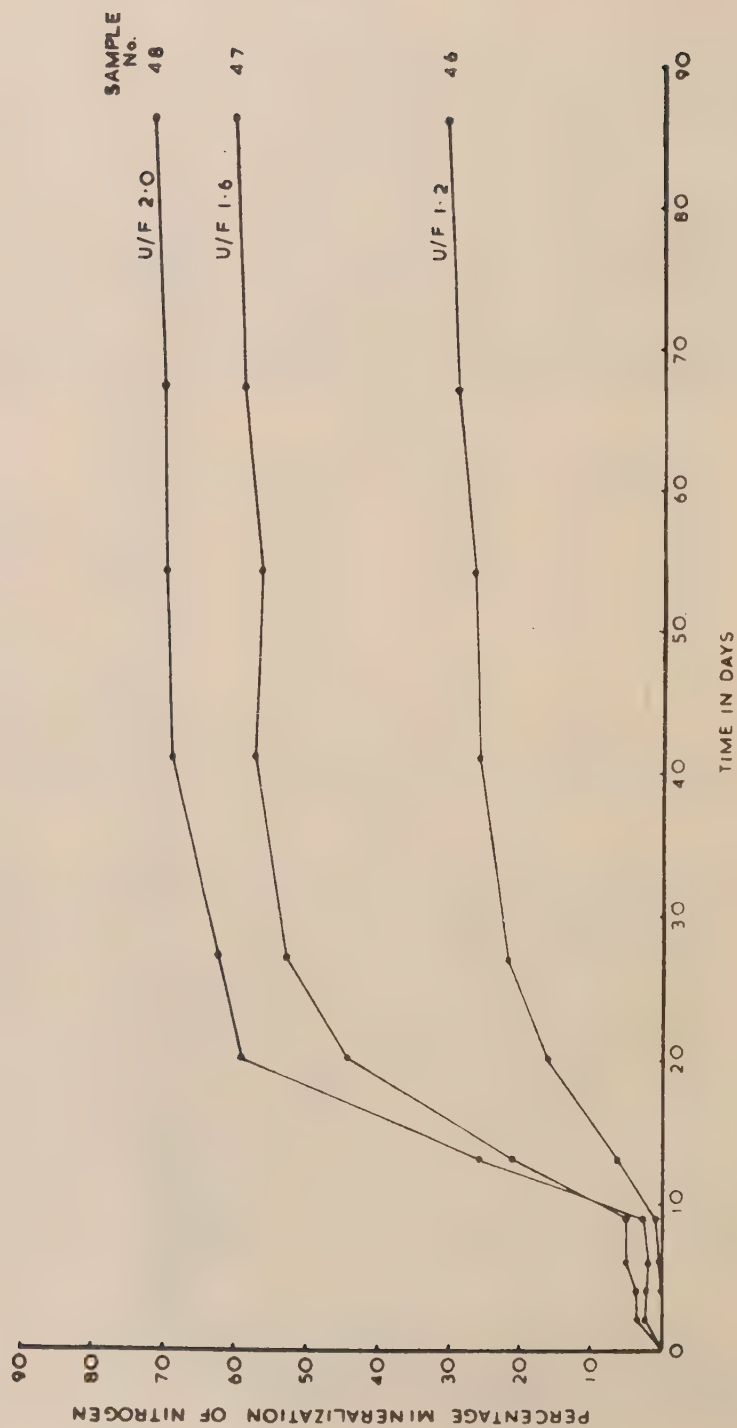


Fig. 5
Mineralization in soil of the nitrogen of urea-formaldehyde samples prepared by method C.

METHOD C

100 g. urea were dissolved in 500 mls. of water, and formalin added to give the required U/F ratio. The mixture was adjusted to pH 3.5 with N/10 phosphoric acid and the flask immersed in a waterbath at 25° C. without mechanical stirring. After 24 hours the solid product was filtered off, washed with water, and exposed to dry at 25° C.

Analytical data for three samples prepared in this way are given in Table IV. The values for soluble nitrogen and free urea are lower than those by method B in Table III, possibly due to more complete washing on the filter. As shown for other series of urea-formaldehyde samples, the U/F ratio of the products and their soluble nitrogen content both increase with increasing U/F ratio of the reactants, whereas the yield decreases.

Values for the percentage mineralization in the soil of the nitrogen of samples prepared by method C are shown in Fig. 5. Relatively little decomposition occurred in the first nine days, but subsequent changes were rapid. There was little tendency for ammonia to accumulate in the treated soils except with samples 47 and 48 after 13 days, and with sample 48 at 20 days. This temporary accumulation of ammonia marks the stage at which rapid decomposition of the urea-formaldehyde materials commenced after the preliminary period of relative inactivity.

TABLE IV
UREA-FORMALDEHYDE MATERIALS PREPARED BY METHOD C

Sample No.	U/F Ratio of Reactants	U/F Ratio* of Products	Total Nitrogen %	Soluble† Nitrogen	Urea‡ Nitrogen	Yield‡
46	1.2	1.13	35.42	1.8	0.1	78.2
47	1.6	1.24	37.20	6.0	3.1	64.6
48	2.0	1.35	36.98	8.1	0.7	46.8

* Corrected for free urea.

† Soluble nitrogen and urea-nitrogen expressed as a percentage of the total nitrogen.

‡ Percentage of the original urea-nitrogen recovered in the products.

The effect of different Periods of Reaction upon Urea-formaldehyde Products

It was considered important to determine whether the properties of urea-formaldehyde materials differed with the period of reaction. The following experiment was accordingly made in which the solid products were removed from the reaction mixtures by filtration after periods of 15, 30, and 60 minutes:—

100 g. urea were dissolved in 250 mls. of water and the pH adjusted to 3.5 with phosphoric acid. To this solution, maintained at 50° C. in a water bath, formaldehyde solution was added dropwise for a period of 15 minutes, the U/F ratio of the reactants being 1.6. In the first preparation the reaction mixture was filtered under reduced pressure immediately after completion of the mixing period. In the second and third experiments the reaction was allowed to continue for further periods of 15 and 45 minutes respectively before filtration. The products were washed on the filter and air-dried at a temperature of 25° C.

The recovery of nitrogen in the products, and their percentage mineralization in the soil, are reported in Table V. All three samples were but slowly attacked in the soil at first, but the later tests showed a relatively high availability of nitrogen in the soil for the first formed product, decreasing as the period of reaction was increased. This result is further discussed in a later section.

TABLE V
THE EFFECT OF TIME OF REACTION UPON THE PROPERTIES OF UREA-FORMALDEHYDE SAMPLES

Sample No.	Time of Reaction	Yield* %	Percentage Mineralization in the Soil				
			4 Days	10 Days	27 Days	66 Days	94 Days
38	15 minutes	11.6	0.7	0.3	14.9	64.1	70.2
39	30 "	38.6	0.6	0.6	12.9	53.3	55.6
40	60 "	55.7	1.6	1.8	9.4	33.2	40.8

* Recovery of nitrogen in the product as a percentage of the original urea-nitrogen.

Discussion of Results

In previous sections of this report various methods of preparation have been selected for trial from among the many possible combinations of experimental factors. The analytical results for samples of urea-formaldehyde material prepared under any one set of conditions are closely related to the initial U/F ratio of the reactants. This relationship is particularly apparent when the products of reaction in concentrated solution are dried without filtration and washing of the products. For such a series of preparations the content of total and soluble nitrogen and of free urea increases with the U/F ratio of the reactants as shown in Table I. Related increases in the U/F ratio of the insoluble portion of the samples are shown in Table II. The influence of the U/F ratio upon the extent of mineralization of urea-formaldehyde products in the soil is illustrated in Fig. 1. That the effect is not merely due to varying amounts of soluble constituents is shown by the results for samples extracted with water before testing, as in Fig. 3. Similar relationships between the U/F ratio and the properties of the products within other series of preparations are shown in Tables III and IV. In these latter cases the products were separated from the reaction mixture by filtration and partially washed on the filter. The increase in soluble nitrogen content with initial U/F ratio is accordingly less marked, but still exists. Within each series the tendency at high U/F ratios is thus for incomplete reaction of the urea, the formation of a high proportion of soluble urea-formaldehyde material, and consequently for recovery of the products in low yield if separated by filtration. Similar relationships for filtered and washed urea-formaldehyde products were reported by Yee and Love (1946)¹ and Clark *et al.* (1948).³

The availability in soil of the nitrogen of urea-formaldehyde materials prepared under different conditions is compared in Table VI. Except for the inclusion of two samples of the A series with those of method B, as shown in Fig. 4, the different materials were not tested simultaneously for mineralization of nitrogen in the soil. In each case, however, the urea-formaldehyde samples were tested in the same soil and under similar conditions. The results given in Table VI are mean values

TABLE VI

COMPARISON OF THE PERCENTAGE MINERALIZATION IN SOIL OF THE NITROGEN OF UREA-FORMALDEHYDE SAMPLES PREPARED BY METHODS A, B AND C. EACH VALUE IS THE MEAN OF DETERMINATIONS AFTER THREE PERIODS OF INCUBATION AS INDICATED IN THE BOTTOM ROW OF THE TABLE.

U/F Ratio of Reactants	Series A		Series A Washed	Series B	Series C
1.2	10.8	10.7	5.1	2.9	29.0
1.4	34.9	—	23.1	24.3	—
1.6	56.9	—	39.3	40.3	59.3
1.8	66.5	—	48.6	60.0	—
2.0	73.7	74.4	46.2	67.9	71.4
2.5	81.8	—	61.3	—	—
3.0	85.5	—	73.0	—	—
Incubation period in days	58, 76 and 104	54, 75 and 104	55, 75 and 104	54, 75 and 104	54, 67 and 86

for the percentage mineralization of nitrogen in the various samples, based on three sampling dates when decomposition was approaching completion. The periods of incubation, chosen as far as possible alike, lie within the approximate range of eight to 15 weeks, the actual values being indicated in the Table. The additional values shown for samples prepared by method A at initial U/F ratios of 1.2 and 2.0 represent independent determinations obtained when these samples were included for comparison in tests on the products of series B. The results are in excellent agreement in the two experiments. Comparison of the relative merits of the various samples in Table VI is complicated by the presence of varying amounts of water-soluble nitrogen. A high proportion of this soluble nitrogen is rapidly mineralized in the soil, and its presence tends to obscure the comparison of availability of the less soluble constituents. Since the primary interest of the present work is in relatively slow-acting fertilizers the mineralization of their sparingly soluble constituents is of fundamental importance. Thus the availability in soil of the nitrogen of samples prepared by method A is seen to be relatively high, particularly at the higher U/F ratios. The practical value of such materials as slow-acting fertilizers is, however, relatively small in view of their high initial solubilities as shown in Table I. The availability of the initially insoluble portions of these preparations (Table VI) is markedly less than for the original samples. At the highest U/F ratio in this

series a relatively high availability was obtained, but the yield of such material is very low. Mineralization of samples prepared by method B was no better than of the washed series of method A at initial U/F ratios up to 1.6, but some improvement is seen at the two highest U/F ratios. The favourable effect of preparation at lower temperatures was in this case probably offset by the dropwise addition of the formalin resulting in somewhat denser granular products. The preparations at 25° C. by method C gave values for percentage mineralization of their nitrogen as high as those of method A at initial U/F ratios of 1.6 and 2.0, and at U/F 1.2 were markedly superior. Furthermore, these favourable results indicate a higher degree of availability of initially insoluble material, the content of soluble nitrogen being relatively low (Table IV).

Conclusions

As is shown in Fig. 1, urea-formaldehyde products can be prepared having rates of mineralization of their nitrogen in soil similar to those of a sample of finely ground hoof and horn under laboratory conditions. Whether or not such samples have any practical application as nitrogenous fertilizers is largely a question of economics, as yet unanswered. None of the samples as yet tested can, however, be said to fulfil all the requirements of an ideal slow-acting synthetic nitrogenous fertilizer. In the earlier preparations by method A the availability in soil of the nitrogen of the samples was closely associated with the content of water soluble constituents. The nitrogen of such samples as had relatively low initial solubilities in water, and which were therefore more likely to be useful as slow-acting fertilizers, proved too inert to be of any practical value. Higher availability of the nitrogen of urea-formaldehyde samples of relatively low initial solubility was indeed achieved by method C at low temperatures. Although samples of this type remained largely inert in the soil for some time (Fig. 5), once active decomposition had started it continued quite rapidly. The problem of combining low initial solubility in water, steady mineralization of nitrogen and high final availability in the soil is thus still unsolved.

Grateful acknowledgment is made to Dr. J. Y. Yee of the Bureau of Plant Industry, Beltsville, U.S.A., for details of his unpublished method for the determination of formaldehyde in urea-formaldehyde reaction products.

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2. STEAM STERILIZATION STUDIES

By J. N. DAVIES and O. OWEN

Investigations on ammonification and nitrification in soil after steam sterilization have been continued.

Soil in one of the experimental houses was steam sterilized by the Hoddesdon pipe system in November, 1950. The pipes were buried to a depth of approximately 9 ins. and steam passed for 20 minutes. Subsequent changes in ammonia and nitrate have been followed in two plots one of which was left completely undisturbed and the other dug over weekly to a depth of 9 ins. immediately after sampling, beginning on the second day after steaming and continuing until the one hundred and seventh day. Neither plot was flooded or planted. Results for the undisturbed steamed plot are shown in Fig. 1. It can be seen that two days after steaming ammonia concentration had risen to 18 p.p.m. thereafter increasing slowly to 26 p.p.m. by the thirty-seventh day. Subsequently ammonia fluctuated between 25 p.p.m. and 34 p.p.m. and 149 days after steaming was still high at 25 p.p.m. A much later sample taken in September, 1951, 10 months after steaming contained 25 p.p.m. ammonia nitrogen but another sample taken a few days later contained only a

few p.p.m. This is referred to later. The changes in the steamed dug plot are depicted in Fig. 2. Here, after the initial rapid rise, ammonia nitrogen increased steadily to 32 p.p.m. on the sixty-fifth day, after which it fell slowly to 3 p.p.m. by the one hundred and seventh day. During the first 65 days after steaming, nitrates, which were initially low at 26 p.p.m. increased slowly with only small fluctuations to 37 p.p.m. Thereafter as ammonia nitrogen fell, nitrate increased rapidly reaching 97 p.p.m. by the one hundred and forty-ninth day.

For comparison with the above results ammonia and nitrate changes in an adjacent unsteamed plot are shown in Fig. 3. There ammonia was low throughout the 149 days, never exceeding 5 p.p.m. Nitrate nitrogen, however, fluctuated widely between the limits of 56 p.p.m. and 124 p.p.m.

Depth Sampling

In view of the possible contamination of the surface soil with nitrifying organisms the ammonia content of the surface $\frac{1}{2}$ in. of a small area of the steamed undisturbed plot was compared with that in a general sample (i.e., 0-5 ins.) 28 days after steaming. Analyses for moisture content and ammonia and nitrate nitrogen are shown in Table I.

TABLE I
AMMONIA AND NITRATE NITROGEN IN SURFACE AND GENERAL SAMPLES OF A
STEAMED UNDISTURBED SOIL, 28 DAYS AFTER STEAMING

	Ammonia Nitrogen p.p.m.	Nitrate Nitrogen p.p.m.	Moisture Content %
Surface $\frac{1}{2}$ in.	33.2	182.1	14.0
General sample 0-5 in. ...	25.7	92.4	19.9

Table I shows that there was little difference between the ammonia content of the two samples but nitrate was 90 p.p.m. higher in the surface soil than in the general sample. A similar experiment a fortnight later again showed high concentrations of nitrate in the surface $\frac{1}{2}$ in. while ammonia was as high as in the general sample. Further investigations were begun to determine the reasons for this marked accumulation of nitrate at the surface.

The steamed undisturbed plot was sampled in layers down to a depth of 9 ins., 48 days after steaming. Fig. 4 shows the results of analyses for moisture ammonia and nitrate nitrogen. Nitrates decreased rapidly with increasing depth from 111 p.p.m. in the 0- $\frac{1}{2}$ in. layer to 47 p.p.m. in the 2 to 3 in. layer, further increase in depth being accompanied by only slight changes in nitrate content. In contrast ammonia concentrations in the different layers were uniformly high. Soil moisture increased progressively with increasing depth.

Similar results were obtained when the unsteamed plot was sampled in depth. From Fig. 5 it will be seen that the 0 to $\frac{1}{2}$ in. layer contained 233 p.p.m. nitrate nitrogen. In the 1 to 2 in. layer the value was 80 p.p.m. Below that nitrate decreased slowly with increasing depth. Ammonia concentrations were low at all depths sampled while once again soil moisture increased with increasing depth.

In contrast to the above results for the undisturbed plots, a depth sampling of the steamed dug plot 51 days after steaming and seven days after having been dug gave the results shown in Fig. 6. Here the effect of diminishing nitrate concentration with increasing depth was not apparent nitrate in the surface $\frac{1}{2}$ in. being only a few p.p.m. greater than that in soil at greater depths. Ammonia was substantially constant at all depths sampled and the moisture gradient was not marked.

The high nitrate concentrations in the top few inches of the undisturbed plots are not likely to be due to activity by nitrifying organisms in view of the high ammonia levels near the surface of the steamed plot together with the low moisture contents. The explanation of the above results may be a physical one. Evaporation of water from the soil causes moisture to move upwards from lower levels to replace that lost and in so doing transports soluble salts concentrating them in the surface layers. Nitrate will thus move freely towards the surface while ammonia which is held in the base exchange complex of the soil is not mobile to any extent.

Evidence in favour of this explanation was obtained by removing soil around two 10-in. blocks of soil in the steamed undisturbed plot so that three vertical surfaces were exposed to the air. The

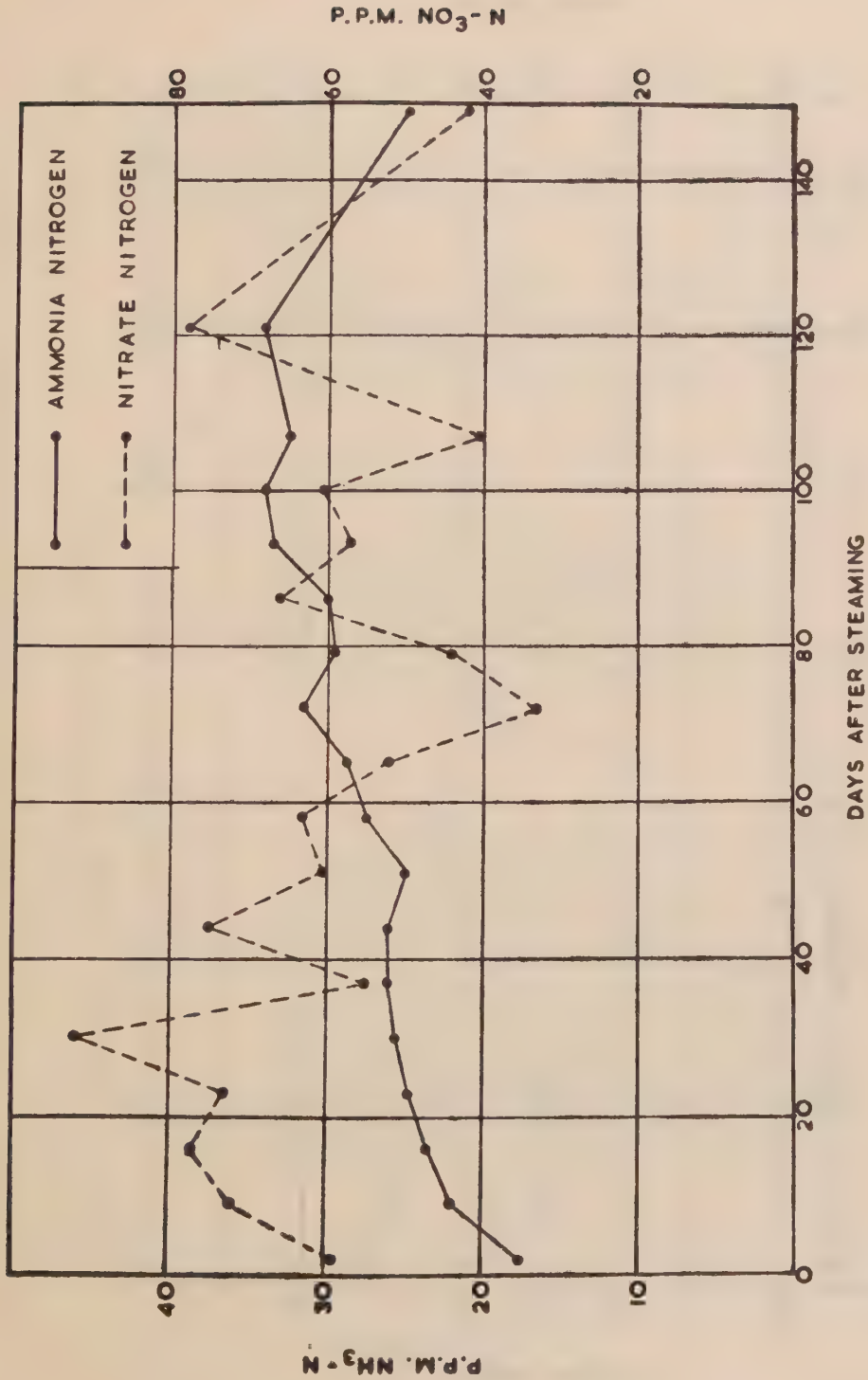


Fig. 1
Ammonia and nitrate production in an undisturbed steamed soil.

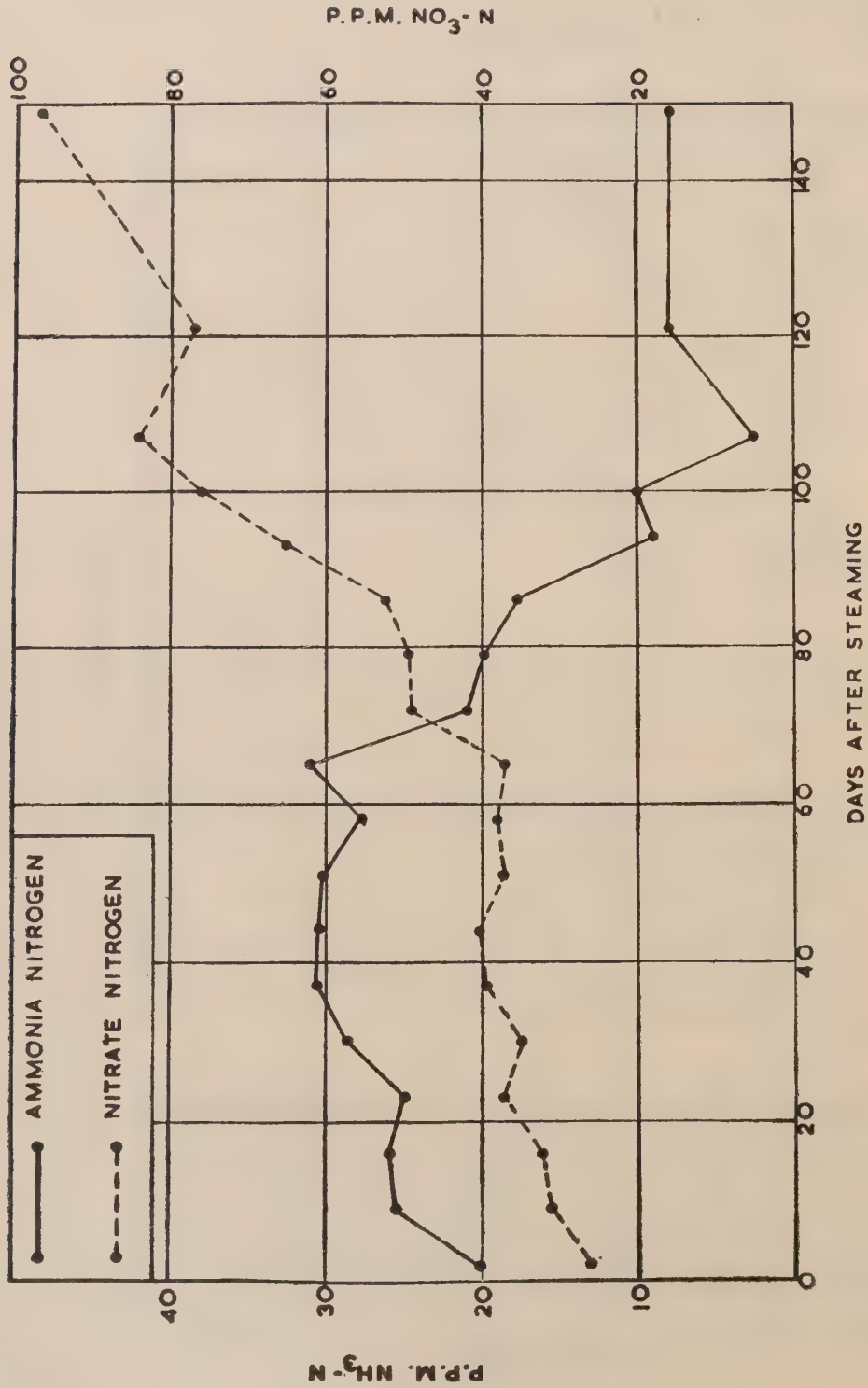


Fig. 2

Ammonia and nitrate production in a steamed soil dug weekly from the second to the one hundredth and seventh day after steaming.

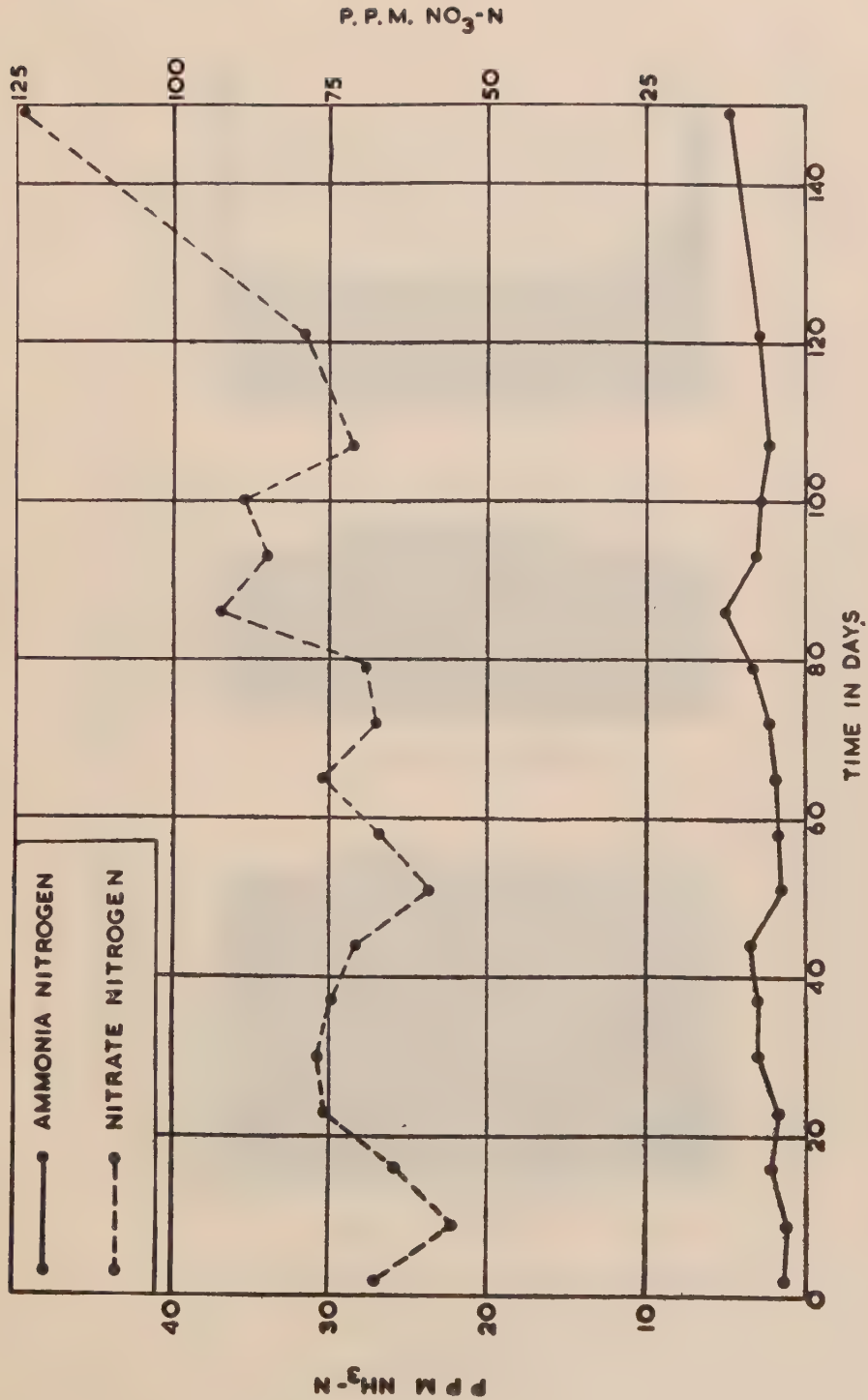


Fig. 3
Ammonia and nitrate production in an unsteamed undisturbed soil.

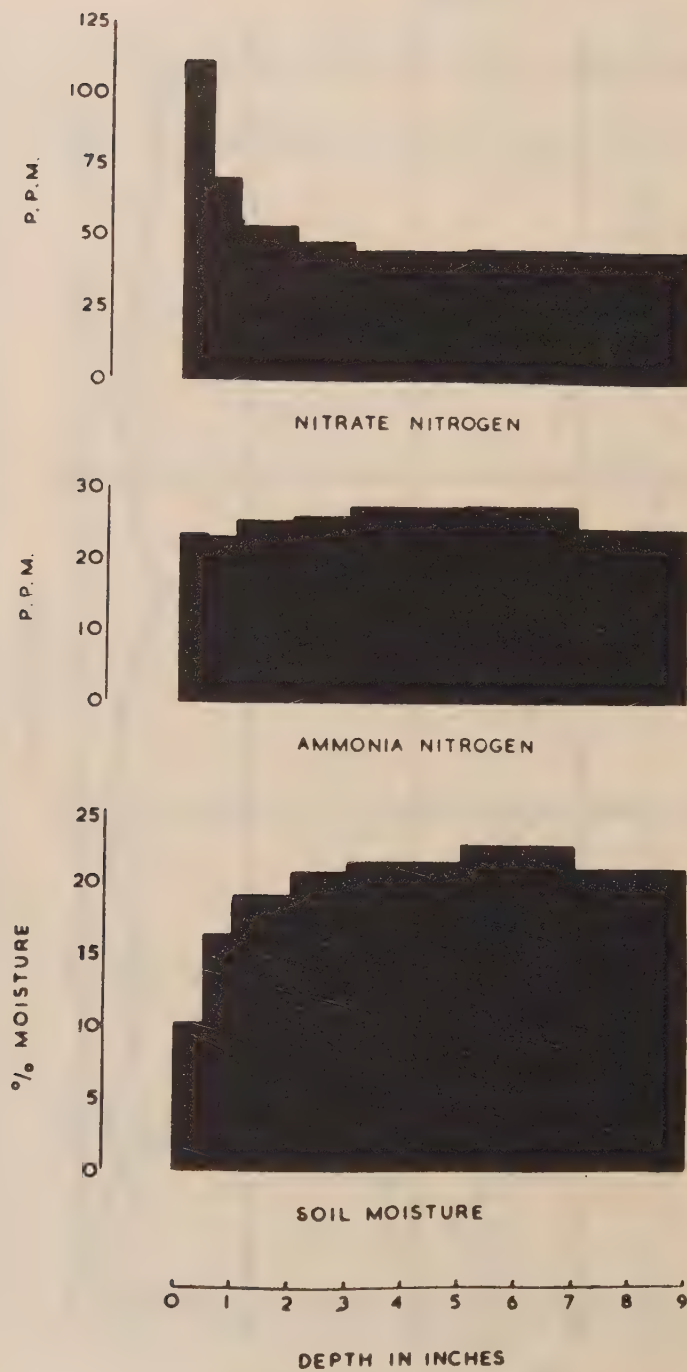


Fig. 4
Nitrate- and ammonia-nitrogen and moisture content of soil from increasing depths of the steamed, undisturbed plot 48 days after steaming.

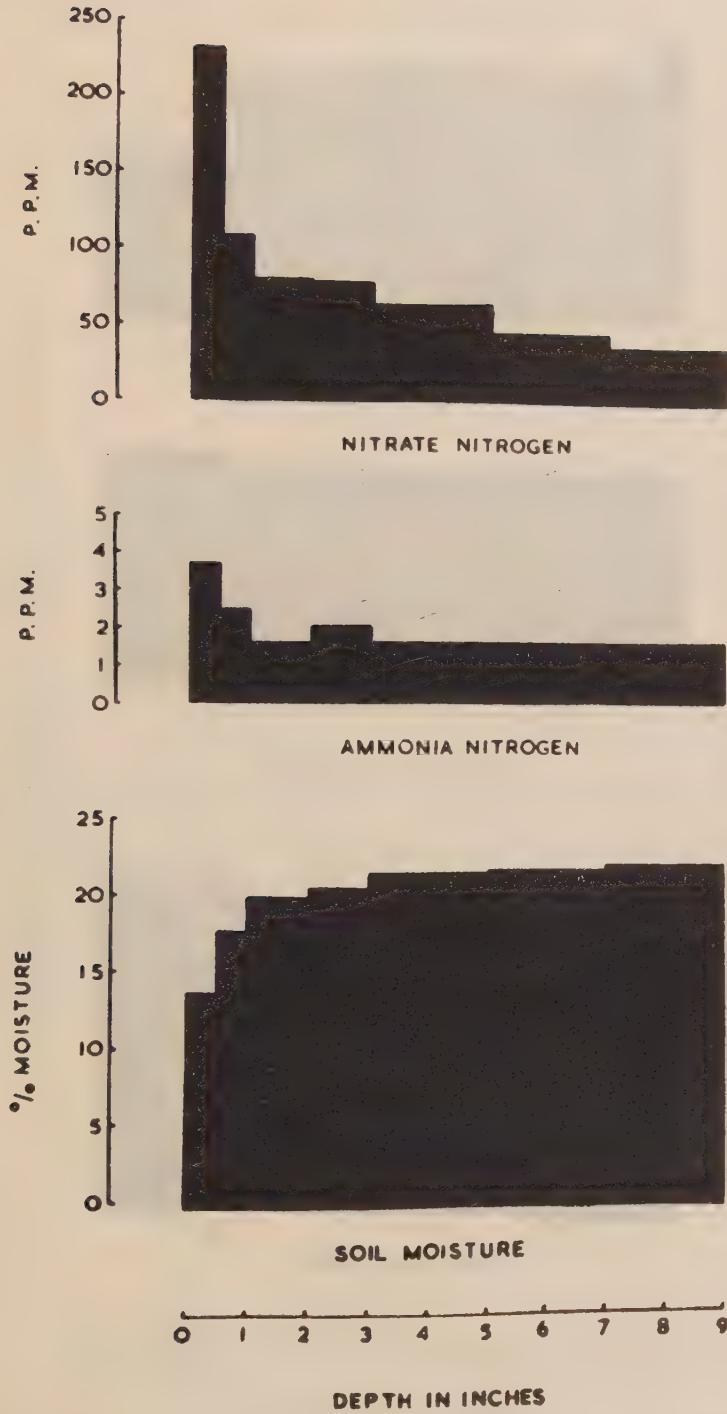


Fig. 5
Nitrate- and ammonia nitrogen and moisture content of soil from increasing depths of the unsteamed undisturbed plot.

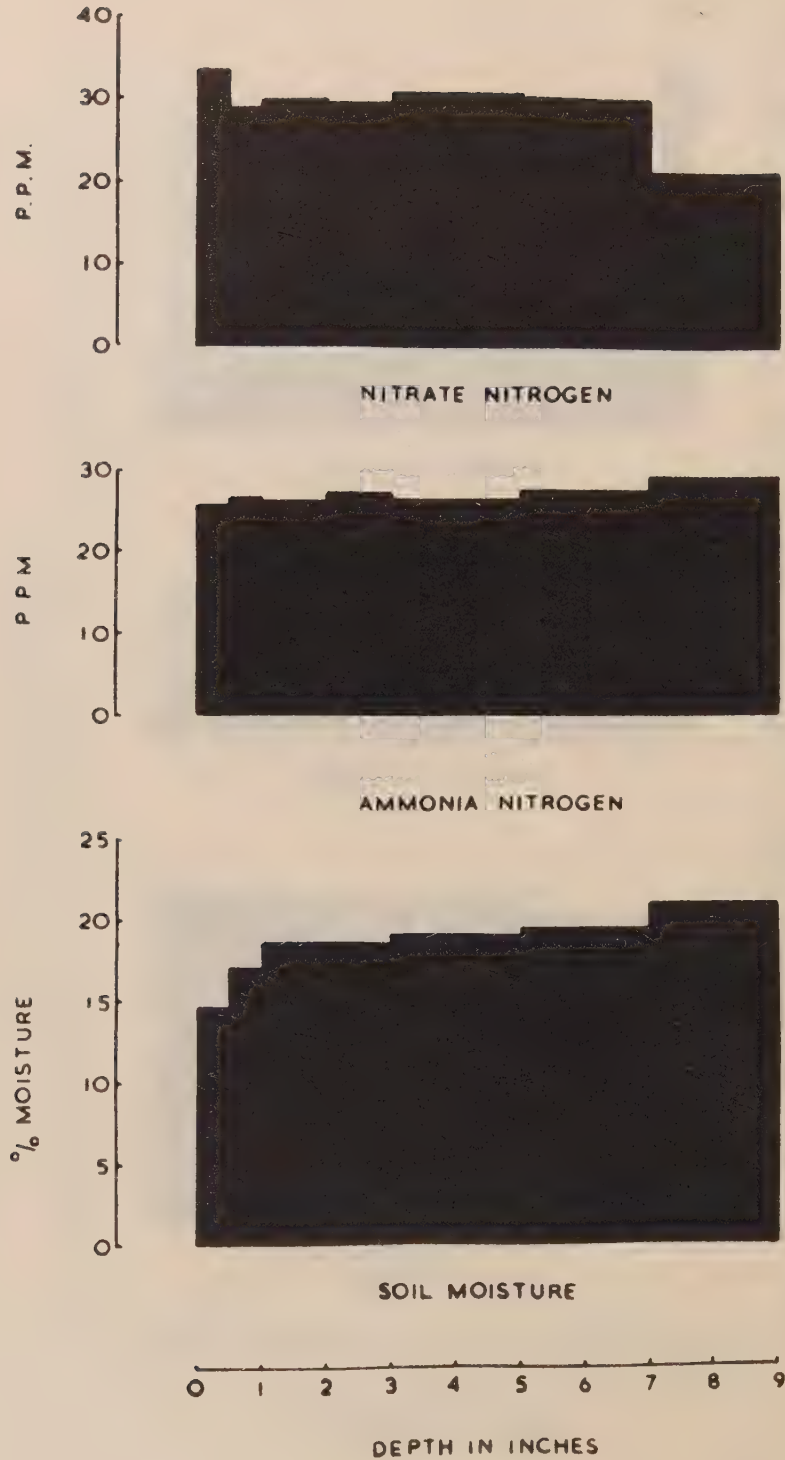


Fig. 6
Nitrate- and ammonia-nitrogen and moisture content of soil from increasing depths of the steamed dug plot (one week after being dug).

other vertical surface was continuous with the main body of the soil. After leaving the blocks of soil undisturbed for a further 53 days one was sampled in depth as previously described, and the other at increasing distances from the vertical soil surfaces. From Table II it will be seen that nitrates accumulated near the surfaces from which evaporation could occur and decreased rapidly with increasing distance from such surfaces, while ammonia was evenly distributed.

TABLE II

AMMONIA - AND NITRATE - NITROGEN AND SOIL MOISTURE IN TWO EXPOSED BLOCKS OF SOIL
AT INCREASING DISTANCES FROM THE UPPER SURFACE

Depth in Inches	Soil Moisture %	Ammonia Nitrogen p.p.m.	Nitrate Nitrogen p.p.m.
0- $\frac{1}{2}$	6.6	28.7	201.2
$\frac{1}{2}$ -1	12.6	29.3	92.3
1-2	15.9	29.6	53.8
2-3	17.1	29.9	52.1
3-5	18.0	29.7	50.1
5-7	19.3	30.0	60.1
7-9	20.3	22.4	53.3

AT INCREASING DISTANCES FROM THE VERTICAL EXPOSED SURFACES

Distance from Vertical Exposed Surfaces in Inches	Soil Moisture %	Ammonia Nitrogen p.p.m.	Nitrate Nitrogen p.p.m.
0- $\frac{1}{2}$	11.7	28.6	295.2
$\frac{1}{2}$ -1	14.7	27.8	96.0
1-2	17.5	27.4	70.2
2-3	18.5	27.4	68.4
3-4	19.5	26.3	73.0
Centre	20.3	26.4	70.8

A general sample taken from the steamed undisturbed plot 290 days after steaming contained 25 p.p.m. ammonia and 54 p.p.m. nitrate. A further two depth samplings taken within a few days of each other in different parts of the plot gave different results. In one case ammonia was low throughout the 9 ins. sampled, while in the other ammonia was high in the top 3 ins. but low at greater depths.

Nitrification of Ammonium Sulphate in Soil from Various Depths

One hundred and twenty-seven days after steaming ammonia concentrations in the steamed undisturbed plot were still high (see Fig. 1) and it was decided to determine the nitrifying capacity of the soil from various depths with ammonium sulphate. Chance contamination risks during the removal of the soil layers were minimised by weighing the soil into 250 ml. conical flasks which were then plugged with cotton wool on the site. On removal to the laboratory the soil in the flasks was moistened as evenly as possible with a solution of ammonium sulphate equivalent to 7.5 mg. nitrogen. Control untreated samples were moistened with an equal volume of distilled water. The samples were then incubated at 23.5° C. and duplicate flasks were withdrawn for analysis after two, five, and eight days' incubation.

Further confirmatory evidence that moisture movement was responsible for the accumulation of nitrates in the surface soil was obtained by determining total water soluble solids, and sulphates in the various layers at the time of sampling. These results are shown with moisture content and ammonia and nitrate nitrogen in Table III.

TABLE III

MOISTURE CONTENT, AMMONIA, NITRATE, TOTAL WATER SOLUBLE SOLIDS AND SULPHATES IN SOIL FROM VARIOUS DEPTHS OF THE STEAMED UNDISTURBED PLOT 127 DAYS AFTER STEAMING

Depth in Inches	% Moisture	Ammonia Nitrogen p.p.m.	Nitrate Nitrogen p.p.m.	Total Water Soluble Solids p.p.m.	Sulphate p.p.m.
0- $\frac{1}{2}$	11.1	26.1	1,024	18,067	5,176
$\frac{1}{2}$ -1	15.7	23.4	307	5,993	1,692
1-2	17.7	24.3	158	4,080	1,432
2-3	19.1	27.9	100	3,747	1,229
3-5	20.3	27.9	77	3,408	1,113
5-7	21.9	25.2	62	2,855	999
7-9	22.9	21.0	50	2,557	893

Concentrations of sulphates, nitrates, and total water soluble solids were exceptionally high in the 0 to $\frac{1}{2}$ in. layer and decreased with increasing depth while once again ammonia was evenly

distributed, although the concentration in the 7 to 9 in. layer was some 20 per cent. lower than in the upper layers.

Ammonia and nitrate values for the control samples from different depths moistened with water and incubated at 23.5° C. are given in Table IV and in Table V data for the per cent. recovery of added nitrogen as nitrate expressed as difference from control are given for the different soil depths.

TABLE IV

AMMONIA AND NITRATE PRODUCTION IN SOIL SAMPLES FROM VARIOUS DEPTHS OF THE STEAMED UNDISTURBED PLOT ON INCUBATION AT 23.5° C.

Period of Incubation in Days	Depth in Inches													
	0-½		½-1		1-2		2-3		3-5		5-7		7-9	
	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N
Initially	26.1	1024	23.4	307	24.3	158	27.9	100	27.9	77	25.2	62	21.0	50
2	27.7	1030	23.0	318	22.4	161	26.3	103	27.4	80	26.8	61	18.2	47
5	26.3	1026	2.5	347	3.7	184	12.0	122	10.4	92	21.6	67	7.5	66
8	20.6	1033	2.9	344	3.7	192	3.1	132	1.6	109	0.9	89	1.2	72

TABLE V

% NITRIFICATION OF ADDED AMMONIUM SULPHATE EXPRESSED AS DIFFERENCE FROM CONTROL IN INCUBATED SOIL SAMPLES FROM INCREASING DEPTHS OF THE STEAMED UNDISTURBED PLOT 127 DAYS AFTER STEAMING

Period of Incubation in Days	Depth in Inches						
	0-½	½-1	1-2	2-3	3-5	5-7	7-9
2	<1	5.9	2.9	1.2	<1	<1	4.3
5	6.5	20.3	14.5	3.9	6.7	6.7	8.0
8	19.1	94.1	92.1	66.7	44.0	19.9	62.5

From Table IV it will be seen that in every soil layer with the exception of the 0 to ½ in. layer sampling, moistening and incubation induced nitrification of the ammonia present in the soil. The rapidity with which the ammonia concentration fell with concomitant nitrate production was most marked in the ½ to 1, 1 to 2, and 7 to 9 in. layers. Soil from the 2 to 7 in. depths was slower in its response as shown by the figures for five days' incubation. After eight days' incubation ammonia concentrations in all the layers with the exception of the 0 to ½ in. had fallen to a low level. In the 0 to ½ in. layer there was only a slight fall in ammonia content after eight days' incubation.

The results of the nitrification experiment given in Table V show that there were marked differences in the response of soil from different depths to the addition of ammonium sulphate. Ignoring the 0 to ½ in. layer nitrification of the added nitrogen was slowest in the 5 to 7 in. layer and almost complete in the ½ to 1 and 1 to 2 in. layers after eight days' incubation. It is of interest that soil from the 7 to 9 in. layer was capable of more rapid nitrification than the adjacent 5 to 7 in. layer. The results for the 0 to ½ in. layer indicate that here the soil was practically sterile as a result of prolonged desiccation.

TABLE VI

AMMONIA AND NITRATE PRODUCTION IN SOIL SAMPLES FROM VARIOUS DEPTHS OF THE UNSTEAMED UNDISTURBED PLOT ON INCUBATION AT 23.5° C.

Period of Incubation in Days	Depth in Inches													
	0-½		½-1		1-2		2-3		3-5		5-7		7-9	
	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N	NH ₃ -N	NO ₃ -N
Initially	8.1	180.8	2.9	141.5	3.1	75.1	2.7	62.4	3.3	60.7	1.4	53.1	1.4	39.0
2	10.5	179.2	1.8	139.6	0.5	73.8	—	62.3	—	59.6	1.1	52.5	—	38.1
5	17.1	186.8	—	148.9	0.5	81.4	1.0	63.4	0.9	61.4	—	61.0	—	41.3
8	11.5	194.8	1.3	152.2	—	82.5	0.2	67.4	0.5	64.6	0.8	57.7	—	41.0

A similar experiment to that just described was carried out with soil from the unsteamed undisturbed plot. Ammonia and nitrate analyses of control untreated samples after two, five, and eight days' incubation at 23.5° C. are given in Table VI and those for samples incubated with added ammonium sulphate are given in Table VII.

TABLE VII

% NITRIFICATION OF ADDED AMMONIUM SULPHATE EXPRESSED AS DIFFERENCE FROM CONTROL IN INCUBATED SOIL SAMPLES FROM INCREASING DEPTHS OF THE UNSTEAMED UNDISTURBED PLOT

Period of Incubation in Days	Depth in Inches						
	0- $\frac{1}{2}$	$\frac{1}{2}$ -1	1-2	2-3	3-5	5-7	7-9
2	—	2.0	5.1	1.6	3.9	3.5	1.9
5	—	18.9	30.7	30.9	36.1	36.0	20.8
8	3.7	83.7	93.3	92.0	91.2	92.3	92.4

From Table VI it will be seen that sampling moistening and incubation stimulated ammonification in soil from the 0 to $\frac{1}{2}$ in. layer, ammonia increasing from an initial 8 p.p.m. to 17.1 p.p.m. in five days; by the eighth day it had fallen again to 11.5 p.p.m. Nitrates meanwhile decreased slightly after two days but subsequently increased 14 p.p.m. by the eighth day. In the other soil layers ammonia concentrations were uniformly low while some nitrification occurred. It will be observed that once again nitrates decreased with increasing depth.

Table VII shows that in contrast to the results for the steamed undisturbed soil, nitrification of added ammonium sulphate was almost complete after eight days' incubation in all soil layers with the exception of the 0 to $\frac{1}{2}$ in. where only 3.7 per cent. of the added nitrogen was recovered as nitrate.

Discussion

As will be seen from the results, regular turning over of a steamed soil in the glasshouse had the effect of hastening the outset of nitrification when compared with undisturbed steamed soil. This is probably due to two effects, first contamination and second improved aeration. Fortuitous aerial infection of the surface soil of the dug plot by nitrifying organisms is effectively introduced into the main body of the soil by the mixing due to digging. That the mixing was efficient is shown by the uniformity of the nitrate concentrations at different depths (Fig. 6) and also by the regularity of the nitrate values in general samples from the dug plot (Fig. 2). In the bulk of the soil the moist conditions prevailing are conducive to bacterial growth and in addition the improved aeration probably exercises a favourable influence on the rapid spread of the infection. As a result nitrification begins comparatively rapidly after steaming and ammonia disappears. In this instance the somewhat slow recolonisation of the soil by the appropriate organisms is probably due to the low temperatures obtaining in the glasshouse for the first 90 days after steaming. During this period the moisture content of the dry plot fell only 3.5 per cent. from an initial 21 per cent. to 17.5 per cent., whereas in the following 60 days when the glasshouse was heated but the plot was not dug, moisture content fell much more rapidly finally falling to 12.2 per cent. on the one hundred and forty-ninth day.

In contrast ammonia concentration in the steamed undisturbed plot remained high for long periods. With no watering or other disturbance the top few mm. of soil are almost air-dry within a few weeks of steaming and any nitrifiers falling on the surface are not likely to multiply rapidly. Any rapid contamination of even the top few inches is thus rendered extremely unlikely. That under these conditions the surface soil becomes virtually sterile is demonstrated by the results for the nitrification of added ammonium sulphate in soil from the surface $\frac{1}{2}$ in. of both steamed and unsteamed plots. It is of interest, however, that in soil from the steamed undisturbed plot sampling, moistening and incubating did stimulate nitrification of the soil ammonia (with the exception of the 0 to $\frac{1}{2}$ in. layer) four months after steaming, though soil from different depths differed markedly in response to incubation with ammonium sulphate. Thus least response was found in soil from a depth of 3 to 7 ins. Soil from the 7 to 9 in. layer was surprisingly more rapid, being similar to that from the 2 to 3 in. layer, while in the layers immediately below the surface $\frac{1}{2}$ in., nitrification of added nitrogen was almost complete. If nitrification of added ammonium sulphate is interpreted as a measure of the degree of contamination by nitrifying organisms, these results show that some contamination had taken place at all depths sampled but additional stimulus was necessary before it became effective. Lower ammonia concentrations were found in the 7 to 9 in. layer and soil from

this depth nitrified ammonium sulphate more rapidly than did soil from the adjacent 3 to 7 in. layer. These results suggest, that contamination besides arising from surface infections acting downwards also arises from the sub-soil where the steaming was not effective. The results for depth samplings of the steamed undisturbed plot 10 months after steaming show that there was also considerable variation in the extent of the contamination possibly due to varying degrees of compaction. The moisture content, however, in the bulk of the soil was still high.

Depth sampling of the undisturbed plots showed that an accumulation of soluble salts occurred in the surface soil. This is quite independent of steaming as it took place in both steamed and unsteamed soil. Other workers have reported similar results in field soils. Krantz, Ohlrogge, and Scarseth¹ working in Indiana on outdoor fertilizer trails have shown that, during prolonged drought nitrate accumulated at the soil surface, returning to the root zone after any moderate rain, while ammonia remained static. Other workers^{2, 3} have demonstrated nitrate accumulation in the surface layers of fallow soil during hot dry periods. Salts have also been shown to concentrate in the outer layer of soil and in the adjacent walls of porous pots.⁴

Evaporation of moisture from an undisturbed soil causes movement of capillary moisture towards the site of evaporation and in so doing concentrates soluble salts at the surface. When mixing occurs as in the dug plot the capillaries are broken, this effect is not found, and nitrate is evenly distributed. Thus nitrate values in the depth sampling of the dug plot show little variation and general samples fluctuated only slightly (Fig. 2), while those for the undisturbed plots varied between wide limits (Figs. 1 and 3). It is probable that the widely fluctuating nitrate values in general samples from the glasshouse reported here and previously⁵ are due to sampling errors, varying quantities of the surface soil being included in the sample. This view is supported by the nitrate concentrations given in soil from the steamed plot at depths below 2 or 3 ins. at different intervals after steaming, results being substantially constant.

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3. THE EFFECTS OF SOME ACUTE MINERAL DEFICIENCIES ON PERPETUAL-FLOWERING CARNATIONS

By J. H. L. MESSING and O. OWEN

Two varieties, White Maytime and Spectrum, were used in these investigations. Cuttings were rooted in pure sand in November. From December 15th half-strength nutrient solution was used and from January 1st, 1951, full-strength solution was introduced. The plants were transferred to the final pots on February 12th.

The experiment was divided into two parts. The first ("early") had the respective nutrients withheld from May 1st. The other batch was continued on complete nutrient solution until the time of opening of the first flower and the treatments were started on August 15th ("late").

To control Red Spider mite it was decided to include 15 p.p.m. Selenium in one batch of the solution. It was used for the first time on May 3rd and discarded on May 11th. The only treatment which suffered was "no sulphur." Selenium was again used in August (excluding the no sulphur treatment) and other measures to control Red Spider were applied by the end of October. The results were satisfactory and the plants were reasonably clean throughout the year.

Addition of alkali was frequently necessary to counteract the tendency of the reaction value of pH 6.5 to fall.

The plants were stopped for the first time on February 13th, and the second stopping started on May 2nd and continued at weekly intervals until all shoots were stopped.

No Nitrogen

The rate of growth was reduced early and retardation was clearly noticeable by June 1st in

the "early" series. This was followed in a few days by yellowing of the older leaves. By June 8th the whole plant was slightly paler green. After that time no growth took place. The leaves on young shoots remain short and nodes were extremely close together. Some shoots were stopped and these did not produce any breaks. In others growth was not sufficiently strong to justify stopping. Although dying of the old leaves was slow very few were still alive at the time when the treatment was discontinued on August 25th. From then on complete nutrient solution was used. Recovery was rapid. The stunted shoots which had not been stopped resumed growth and produced normal flower stems and flowers. When one of these flowers was cut normal development of breaks took place on that stem. On the other hand the shoots stopped at the beginning of "no nitrogen" treatment showed no signs of recovery. All axillary buds appeared to be dead and the shoots died completely.

In the "late" treatment reaction was slower. The rate of growth of the young shoots was reduced and the number of sideshoots produced very small. Noticeable loss of colour of the whole plants did not occur until the end of October. There was no effect on flowers produced from buds already developed.

The regular dying of the old leaves from tips backwards across the whole width of the leaf and the light colour of the dead tissue are characteristic of this deficiency. On reaching the base of the leaf dying continues so that the stem becomes light yellow. There was practically no difference in the reaction to this treatment between the two varieties.

No Phosphorus

There were no characteristic symptoms by which the deficiency can be easily identified. The plants were stunted, the shoots considerably thinner and the flowers were slightly smaller.

Old leaves died at an abnormal rate and in an irregular manner, most often starting at the base of the leaf, and eventually becoming brown. White Maytime was more affected than Spectrum. No symptoms were noted in the "late series" up to the end of the year.

No Potassium

Some slight reduction in the rate of growth and thinner shoots were the first symptoms of this deficiency. Early in July characteristic symptoms were noted on the middle leaves. The tip ends of these leaves showed slight loss of colour and the part of each leaf extending from the tip down to a third or half of the total leaf length became suddenly covered with light-coloured necrotic, sunken spots, irregular in shape and size. From then the symptoms developed very quickly. The bottom leaves died rapidly, so did the middle leaves showing the above symptoms. The spots grew bigger and merged together until the entire tip end was dead. Further irregular dying back of the leaf took place, sometimes along the edges, sometimes in irregular bands across the leaf. A characteristic feature is that when the die-back of the leaf approaches the base it stops or slows down considerably so that the internodes and even the base of the leaf remain green. The dead part of the leaf is twisted and darker in colour than on the no-nitrogen treatment. These symptoms were observed on White Maytime.

Spectrum reacted rather differently. Dying of middle and old leaves started about four weeks later than on White Maytime. Effects generally were similar in character to those described for the Maytime with the notable exception that the necrotic spots did not develop. The tip scorch phase and twisting were the first indications.

Very weak thin stems and extremely poor blooms were produced on both varieties. In most cases flower stems collapsed at about the third internode from the top and wilted without the buds opening properly.

The "early" treatment was discontinued on November 8th when a large number of shoots were dead and no further growth was taking place. Practically no recovery occurred when complete nutrient was restored.

No symptoms were noted on the "late" treatment up to the time of reporting.

No Calcium

Tip burn on young leaves was noted on both varieties. It appeared on June 8th, on Spectrum, and on June 11th on White Maytime. It differs from any other tip burn in that it has a definite constriction at a certain distance from the tip. Later on the whole tip becomes narrow and often bends at a right angle to the rest of the leaf blade, towards the upper surface. Although these

symptoms spread rapidly to the lower leaves practically no dying back of the individual leaves occurs. The youngest leaves are most affected and the complete death of the growing point takes place about four weeks after the appearance of the first symptoms. Some growth of the plant as a whole took place during that period but the resulting stems were thin and the leaves were small and narrow. The next stage was the appearance of the lesion of dying tissue just above the second pair of leaves (from the top) and collapsing of the stem at that point. It worked down the stem, new lesions appearing just above the next lower pair of leaves and so the death occurred by stages. Side shoots were very prolific, light green in colour, and thin. They soon died in the same way as old ones. The old foliage acquires a dark dull green, unhealthy colour. Both varieties showed exactly the same symptoms, the only difference being the narrow red-violet coloured border between the dead tip and the rest of the leaf on Spectrum. In the "late" series reaction to this treatment was very slow. The growth became slightly poorer, but symptoms were erratic and somewhat ill-defined.

No Magnesium

The appearance of the first symptoms was somewhat confused by the slight reaction at that time to Selenium treatment.

What appeared to be early symptoms, slight interveinal yellowing of middle and young leaves were noted in the second half of June on Spectrum and early in July on White Maytime. Stems were very weak and thin on both varieties, and the leaves narrow. About July 20th both varieties showed very sudden and severe interveinal yellowing on the middle and old leaves. Whole plants became virtually yellow with only the veins remaining light green. Growth was arrested at that stage and old foliage was dying.

Very characteristic symptoms consisting of a narrow, regular necrotic band across the leaf blade near the base, appeared on August 6th on White Maytime. It spread quickly so that in a short time most of the foliage in the middle of the plant was affected. On some stems as many as six consecutive pairs of leaves collapsed at the same time. The bands remained unchanged and the collapsed leaves retained their turgidity. The same symptoms developed on Spectrum three or four weeks later. The bands were less regular and wider. Some tip scorch also occurred and there was a tendency for the bands to widen. There was always a reddish-violet border around the dead necrotic parts.

Blooming was comparatively early but the blooms were small and of very poor quality, often wilting before opening fully.

No reaction was observed in the "late" series.

No Sulphur

No plants in the "early" treatment survived after the selenium treatment for Red Spider mite, although complete solution was substituted one week after the first symptoms of injury appeared.

Some spare plants were started—White Maytime on May 23rd and Spectrum on July 6th—25 per cent. of those were again treated with selenium but the plants were fully developed at the time and they showed little ill effect and made normal growth.

By about the middle of July reduced rate of growth of White Maytime was noted and stunting became acute soon after. Stiffness of the stems was observed even earlier and should be really regarded as the first symptoms of this deficiency. Chlorosis of the tops followed and the whole plant became bright grassy green. The most acute loss of colour occurred on the actual nodes and on the basal parts of young leaves. No part of the plants died but growth was very slow, internodes were short and the leaves small. Bud development was retarded and it took about six weeks from the time the first colour was shown until the flower was fully opened. The flowers were very small but of a good shape and texture.

White Maytime appears to be more susceptible than Spectrum, but the results are not quite comparable as the former was started earlier on this treatment.

In the "late" experiment there were few signs of disorder and only the stiffness of the stem was well defined.

It may be pointed out that the no-sulphur treatment was the only one where the element in question was deliberately added in small amounts. Copper, zinc, aluminium, and nickel were all added in the form of sulphate. It meant 0.16 p.p.m. SO_4 in the no-sulphur solution (equivalent to 0.05 p.p.m.S).

No Boron

In the "early" treatment the first signs were observed on Spectrum at about June 21st and consisted of tip scorch of the young leaves. It developed slowly and more acute loss of colour of whole tops occurred at about July 1st. Even then the only other signs was stunted growth.

White Maytime was even slower in developing symptoms, but the effect on growth was more acute and internodes were very short.

All growth had ceased by the middle of July and the death of all growing points followed shortly in White Maytime, Spectrum resisting longer. Dying back took place, but quite vigorous growth of the sideshoots, many to every node, started and characteristic bushy growth resulted. The new shoots were thin, with short internodes.

In the "late" treatments the effects appeared even quicker. The stiffening of the flower stems was noted about September 11th. On September 17th the distortion and transparency of the edges of the outermost petals was observed. On September 20th young buds were dying on White Maytime and tip yellowing of young leaves appeared. Younger shoots had their growing points dead in a matter of a few days. The symptoms appeared on Spectrum with only slight delay, edges of petals becoming nearly black and flowers had an untidy ragged appearance.

In both "early" and "late" experiments the symptoms on young leaves were different on White Maytime and Spectrum. Those on White Maytime became stiff, remained short and their tips turned yellow. They remained in that state for a considerable time and eventually death was rather sudden, being preceded by hardly any necrosis or tip burn.

In Spectrum only slight loss of colour occurs and early tip scorch sets in. The dried parts become twisted and small round "lumps" are scattered all over the leaf, specially well visible on the lightest parts. At the same time red pigment appears abundantly in irregular patches. The leaf is slowly dying back from the original tip burn.

On the whole there is the tendency for symptoms to appear earlier on Spectrum especially when young plants are used, but White Maytime suffers more, its growth being arrested very early and death of the shoots following almost immediately.

Distilled water was used for this treatment. When demineralised water was used for preparing nutrient solution the only sign of abnormality was abundant growth of side shoots, their weakness and slower rate of growth. No death of any part of the plant occurred.

Although splitting of the calyxes was carefully studied it cannot be at this stage related to any particular treatment.

Plants were also grown without zinc, manganese, and iron respectively, but no reactions were noted up to the end of December.

Grateful acknowledgement is made to Mr. C. J. Horwood who supplied the cuttings for the plants used in this work.

4. LIME-INDUCED MANGANESE DEFICIENCY IN GLASSHOUSE ROSES

By D. M. MASSEY and O. OWEN

Treatment of rose soils to correct manganese deficiency in the trees has been extended during the year. The varieties have included Roselandia, Lady Sylvia, Talisman, Autumn, and Richmond. The rate of application has been maintained at 4 ozs. per sq. yd. This dressing of sulphur pricked into the top 4 ins. of the soil corresponds to approximately 0.2 per cent. in the soil. The fact that, in the main, correction of the disorder has followed this application indicates that the concentration of sulphur is reasonably correct for practical purposes. There remained, however, the question as to what effects heavier dressings would produce. Accordingly a composite sample of soil from an affected greenhouse was divided and the sub-samples mixed intimately with varying amounts of flowers of sulphur. They were then incubated at 23° C. for seven weeks. Fig. 1 shows the changes in the pH values week by week during the period and final values are as follows:—

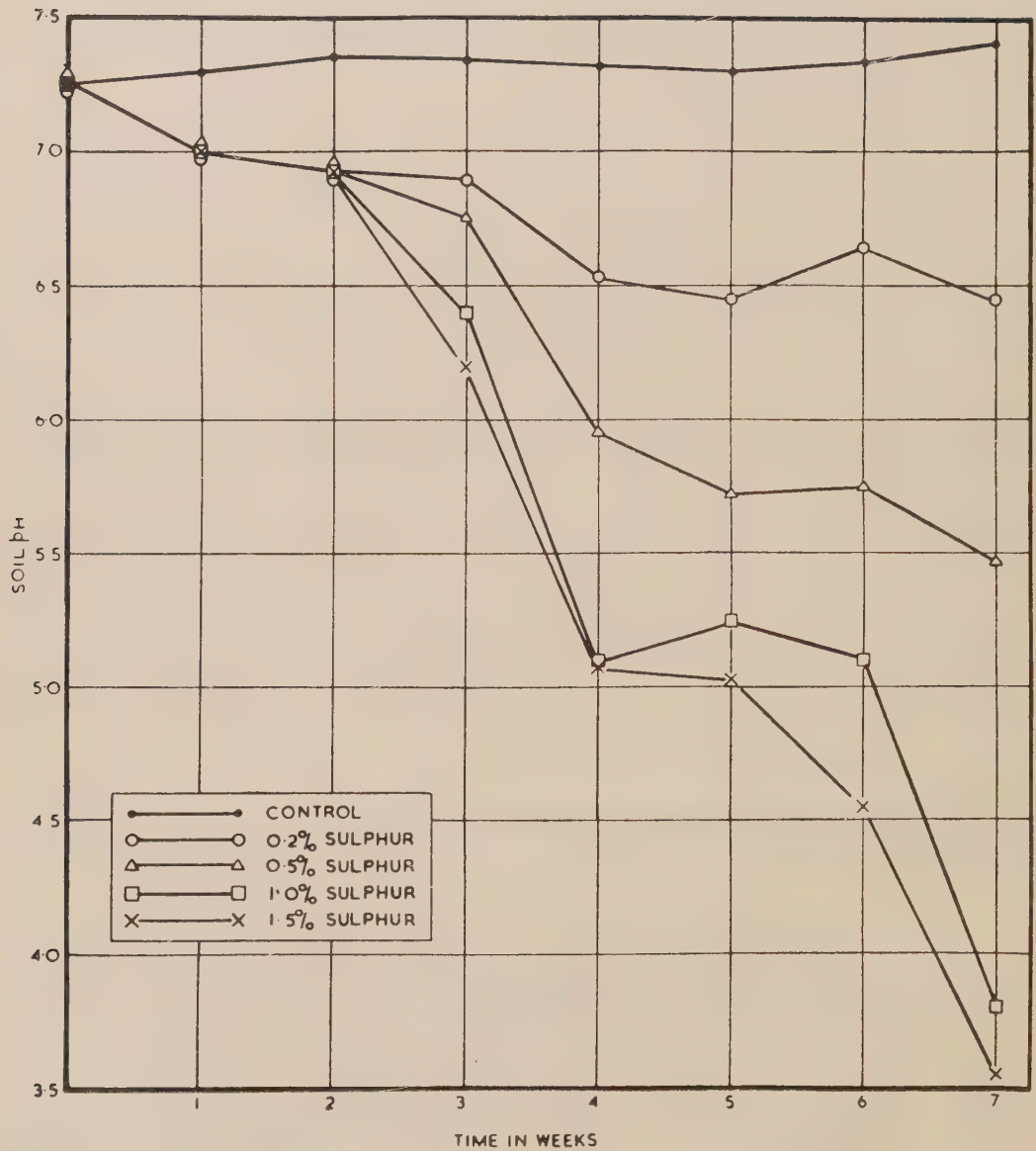


Fig. 1
The effect of various concentrations of sulphur on soil pH.

Original	...	...	...	...	...	7.33
,,	0.2	per cent.	sulphur	...	...	6.44
,,	0.5	,,	,,	...	...	5.47
,,	1.0	,,	,,	...	...	3.80
,,	1.5	,,	,,	...	...	3.55

The curves show that reduction of pH values is not complete except possibly at the 0.2 per cent. level and further incubation would have produced lower values. It is doubtful, however, whether reduction of the reaction below pH 6 is desirable and again it seems that the dressing of 4 ozs. per sq. yd. is justified.

In all cases the sulphur treatment was carried out when the trees were dormant. When growth was started for the season the varieties Lady Sylvia and Roselandia made normal growth except that the mottle characteristic of manganese was either absent or reduced to negligible proportions. It was noteworthy, too, that growth generally was sturdier than in the untreated trees. The varieties Autumn and Talisman, while showing little or no chlorosis, did suffer slight retardation in growth during the early season, but this did not persist, and eventually they were considered to be better than those of the same varieties in untreated plots.

The variety Richmond merits particular mention. The treated trees suffered a decided retardation in development generally during the first few weeks of the growing season. This variety is not a particularly strong one ordinarily. At the relevant times, however, growth was definitely weaker than usual and despite the fact that the foliage was of a good colour the new growth was almost stunted. Later, growth accelerated and by mid-season was quite satisfactory. When autumn came the treated trees were in considerably better condition than those untreated. Samples of foliage taken in May from both lots of trees gave the following analytical values:—

	N	Ca	Mg	P	K	Fe	Mn
Sulphur-treated	2.37%	1.28%	0.36%	0.26%	1.79%	87 p.p.m.	106.5 p.p.m.
Untreated ...	2.28%	1.29%	0.34%	0.20%	1.84%	71 p.p.m.	23.5 p.p.m.

These results show that the most pronounced effect of the treatment is a considerable increase in the manganese content of the trees.

The retardation of growth, already recorded, still remains to be explained. The fact that Richmond was so definitely affected may be related to its comparatively shallow rooting habit. It is grafted on *Rosa manetti* whereas most of the other varieties are on *R. canina*. The effect may be due to the reduction of pH following the treatment: it may be due to the sulphur itself; or the formation of some injurious compounds during its oxidation. It may also be that normal soil processes are upset.



VI. PLANT PHYSIOLOGY

By E. R. LEONARD

There is little knowledge of the quantitative development of tomato roots in glasshouses in relation to growth of the tops, where the interaction of light and temperature have been taken into consideration.

A glass-sided box and glass-lined trench, sufficiently large to include the greatest depth of tomato roots ascertained so far, have been used to study during the growing season, the inter-relations of the two portions of the plant under commercial conditions.

It has been found for one variety, during one season, and under one type of cultural operations, that:—

- (1) Stem length increases regularly throughout the growth period.
- (2) Leaf number on the main stem shows a steady rate of increase until about the time that ripening of fruit begins, and then a slow, progressive decrease. Due to "leafing" an early, steady value is reached.
- (3) Roots of both 1 mm. and less than 1 mm. diameter show four consecutive phases of growth:—
 - (a) a rapid rise to a peak value;
 - (b) followed by marked decline;
 - (c) There is then a gradual rise, with short-term fluctuations, to
 - (d) a new, sustained high level towards the end of the season in the thinner roots, but a continued decline in the thicker ones.

These four phases in root development are also seen if the total root length is sub-divided into the lengths present in successive vertical layers of soil.

The peak of root development between phases (a) and (b) is associated with the setting of the first fruit trusses and the recovery phase, (c) with the removal, on harvesting, of the fruit from the lower trusses.



V. GROWERS' NOTES

I. DIDYMELLA STEM ROT OF THE TOMATO

By P. H. WILLIAMS

During the past nine years accounts of the investigations on *Didymella* Stem Rot have appeared in successive Annual Reports. These reports are here summarised in order to give a connected account of the work which has been done on this disease.

Symptoms

Didymella Stem Rot is usually first noticed when scattered plants collapse suddenly during the early summer. Examination shows a dark brown, slightly sunken area girdling the stem at or near soil level. The outer tissues are soft and easily scraped away and embedded in this rotten tissue are the pycnidia or spore cases of the fungus which are visible with a hand lens as small black dots. Under moist conditions, spores ooze out of the pycnidia to form slimy pink masses. Later in the season, similar lesions occur higher up the stem. In some cases, only stem lesions occur.

The stem lesions may be confused with those caused by *Botrytis cinerea* and *Phytophthora parasitica*. They may be distinguished by the fact that they are dark brown in colour and the surface layers are easily scraped away as well as by the presence of pycnidia. Lesions caused by *Botrytis* are paler and the surface remains hard. The fungus also usually grows out to form a greyish brown mould. In *Phytophthora* Stem Rot the pith is destroyed so that the stem sinks in and the outer layers are thrown into longitudinal folds. The colour of the lesion is greyish-green. If the infected stem is placed under moist conditions, the fungus grows out as a fluffy white mould.

Under glass, the fruit is not usually attacked by *Didymella* until late in the season, but outdoors fruit rot is very common and in some cases may be the only sign of attack by the fungus. The spores of the fungus lodge under the calyx and the mycelium penetrates the fruit, causing a softening of the tissues. The tissues turn black and hard and large numbers of pycnidia are formed in the blackened tissue. The fruit may or may not drop off. In the latter case the fungus may grow back into the truss and stem.

Occasionally the fungus is found attacking the tap root and large roots below soil level. Under very moist conditions, the leaves and the sepals of the flower may also be attacked, brown spots with numerous pycnidia appearing on them.

Infection is mainly found on older plants, but they may become diseased at any stage of growth. Mrs. Sheard obtained infection of seedlings growing in contaminated soil on one occasion but was unsuccessful when she repeated her experiment. She found that plants growing in size 32 pots were more susceptible than those growing in "60's."

Infection is greatly favoured by wounds in the stem and it is found in many cases that lesions have originated from infection of wounds left when removing leaves and sideshoots.

Other Hosts

In Mrs. Sheard's experiments egg plants were readily infected by *Didymella* whether wounded or not. Wounded but not unwounded plants of the Woody Nightshade, *Solanum nigrum*, a common weed, were infected early in the season. Later unwounded plants could also be infected. Potatoes, which have been claimed as another host of the fungus, could only be infected late in the season when they were dying off. Slight infection was obtained on wounded stems of tobacco and *Nicotiana glutinosa*.

Small described a disease of the strawberry caused by *Diplodina lycopersici* the name by which *Didymella* was formerly known. He found that his fungus from strawberry would infect tomato, cucumber, and tobacco plants. A culture isolated from tomato fruit caused typical symptoms on strawberry plants. Mrs. Sheard was unable to repeat his results, but recently a further case of the strawberry disease has been reported.

Liesau reports that a number of solanaceous plants are attacked, including the winter cherry (*Solanum elaeagnifolium*), Bittersweet (*S. dulcamara*), *Physalis*, *Datura stramonium*, and *Petunia*.

It seems possible that the two weeds, *Solanum nigrum* and *S. dulcamara*, might become infected naturally and that the fungus might overwinter on their dead remains. Care should be taken, therefore, to destroy them. This applies particularly to the neighbourhood of tomato crops in the open.

Sources of Infection

(a) SEED

Several workers have suggested that the fungus may be seedborne. In Mrs. Sheard's experiments, however, seedlings and young plants remained healthy even when pycnidia were present on the seed coat. Nevertheless, the fungus may persist in the soil around the plant and infect it later in the season when it is more susceptible. Taking seeds from crops in which fruit rot is present is therefore not to be recommended. The safest source of seed is from crops grown under glass where fruit is only rarely infected.

(b) SOIL

The basal lesions probably arise from contaminated soil. Soil may be contaminated with remains of diseased plants, or by spores blown in from outside. The growth of the fungus in soil is favoured by the presence of carbohydrate material such as straw and to a less extent by stable manure.

Recent work suggests that the fungus is able to survive in an active state more readily in wet soil than in soil that has dried out provided the temperature is sufficiently low. On the other hand, the mycelium appears sensitive to heat, four weeks' exposure to 80° F. causing a very great reduction in the amount of living mycelium in the soil. After that, however, it appears to remain fairly constant for a period of at least 12 weeks suggesting that part of the mycelium is more resistant. It is possible that the dark, thick-walled mycelium which is formed in culture especially when grown upon sand containing 3 per cent. oatmeal may be able to resist unfavourable conditions. When such cultures have been mixed with soil either sterilized or unsterilized, the fungus has survived for 43 weeks and has retained its power of infecting plants. The fungus may therefore remain in the soil during the winter unless steps are taken to destroy it.

(c) SPORES

Not only may soil be contaminated by spores blown in from dead plant remains outside, but direct infection of the plant may take place as in the production of lesions high up on the stem. Mrs. Sheard trapped spores from the air of an infected nursery all the year round, thus demonstrating the importance of this source of infection. The spores originate from diseased plant remains on rubbish heaps outside. Infection of sterilized soil from this source is of particular importance since the fungus grows more rapidly in sterilized soil than in unsterilized and the whole of the labour and expense of sterilizing may be lost if steps are not taken to eliminate this re-infection. (See below.)

The disease may be spread from lesions at the base of the stem in the process of watering, the spores being either washed to the bases of other plants or splashed up on to the stems. In cases where the disease is serious, a mulch of peat may help to stop this spread. Straw should not be used as the fungus is able to grow and fruit on it.

The spores are very resistant to cold and drying. While still in the pycnidia they are able to withstand freezing at 23° F. for at least 12 weeks. In pycnidia on dry stems they can survive for 11 months and in a suspension dried on slides for 17 days. They are therefore capable of surviving the winter in the stems and may also be carried long distances by air currents when free from the pycnidia.

(d) OTHER SOURCES

As mentioned above, *Didymella* is able to survive over the winter in diseased stems on rubbish heaps and spores from such a source have been detected in the air on nurseries throughout the winter and spring. The fungus will also grow on straw, hay, rotten wood, cardboard, etc., all of which may be contained in a rubbish heap. It is therefore important to destroy all rubbish.

Canes, stakes, and wires used for supporting plants have all been shown to harbour the fungus from one year to the next either as spores in crevices or as mycelium in adherent soil. They must be sterilized before they are used again by soaking in 2 per cent. formaldehyde. The fungus has also been isolated from fillis used for a diseased crop and therefore new fillis should be used each year.

Effect of Cultural Conditions

Didymella lycopersici grows best at 68° F. to 70° F., a temperature which is rather low compared with the optimum temperatures of most tomato pathogens, about 77° F. It is therefore more active

in cool, dull seasons than in hot and sunny periods. The lower atmospheric humidity in hot seasons also lessens the risk of infection by drying up wounds more quickly and by making conditions less favourable for spore germination.

In some fertilizer trials, some evidence was obtained that those plants which received most nitrogen or least potash became infected sooner. Varying the amount of these fertilizers, however, made no difference in the final proportion of plants which became infected.

Control

During the growing season little can be done to combat the disease by means of sprays or dusts. A number of substances have been tested, but none have given consistent results in practice.

Cutting out the lesions as is done with *Botrytis* Stem Rot has been advocated, but it has been found that the fungus extends 10 ins. or more beyond the visible limits of infection. Even when a large amount of tissue is removed the fungus invariably grows out again at the edges of the wound.

The best method of preventing the spread of the disease is by removing and burning diseased plants as soon as seen. Where basal lesions are concerned, the roots should be removed carefully and the soil treated with a 1-in-16 000 solution of ethyl mercury phosphate at the rate of $\frac{1}{2}$ gall. per square yard. Where only a few isolated plants are involved it is sufficient to treat the soil for about a yard around each plant, but if infection is extensive it may be necessary to treat the whole house. The method of application and the precautions to be observed in using this substance are detailed below. If replanting, the hole for the new plant should be filled with the solution and the new plant put in when it has drained away.

The most important aspect of control of this fungus lies in the destruction of all possible sources of infection and by strict attention to hygiene. Where possible, the houses should be fumigated at the end of the season by burning sulphur. The plants should first be cut off close to the ground and then sulphur burned at the rate of 1 lb. per 1,000 cu. ft. This fumigation kills many of the spores and helps to dry up the plants. The plants should then be removed and burned together with the roots and all other rubbish. If a mulch has been used it should be removed and burned. More sulphur can then be burned or the house sprayed with 2 per cent. formaldehyde or 1-in-100 tar acid sterilizing fluid, the soil being also sprayed. After burning sulphur, the house should be well washed down, to remove zinc sulphate from wires and wood painted with zinc base paint.

The soil should then be thoroughly sterilized either by steam or formaldehyde. In order to guard against re-infection the surface of the soil should be treated about three weeks before planting with 1-in-16,000 ethyl mercury phosphate.

Owing to the poisonous nature of this compound certain precautions must be taken when using it. The operator should wear rubber gloves and other protective clothing and special care should be taken when handling the solid or concentrated solutions not to allow it to come in contact with the skin. To lessen this danger, one firm markets it in bottles containing sufficient for 40 gallons of solution and a dye is mixed with it so that it may be readily detected on the skin and washed off immediately.

The solution is applied with a can to small areas and with a spraying machine fitted with a fine rose in place of the usual nozzle when whole houses have to be treated. The solution must not be applied where straw mulches have been put on since amounts of vapour detrimental to health and to fruit setting are evolved.

Other measures which should be taken to lessen the chances of the disease recurring include soaking canes and wires used to support the plants in 2 per cent. formaldehyde, treating pots and boxes used in propagating with steam or formaldehyde and using new fillis.



APPENDIX "A"

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APPENDIX "B" MANURIAL TREATMENT IN TOMATO EXPERIMENTS (Except plots in Appendix C)

House	Plot	Sterilisation	BASE TREATMENT					TOP DRESSING							Nutrient Feeding by Solu-feeder
			Lime	Stable Manure	Hoof and Horn	Bone Meal	Sulphate of Potash	Sulphate of Ammonia	Sulphate of Potash with first Watering	Balanced Mixture	Dried Blood Mixture	Sulphate of Ammonia	Superphosphate	Sulphate of Potash	
1		Steam	1 ton per acre						5 cwt. per acre	9 applications	None				
3	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	8 applications					
	2	"	"	"	"	"	"		"	"					
	3	"	"	"	"	"	"		"	"					
	4	"	"	"	"	"	"		"	"					
	5	"	"	"	"	"	"		"	"					
	6	"	"	"	"	"	"		"	"					
	7	"	"	"	"	"	"		"	"					
4	8	"	"	"	"	"	"		"	"					
	4	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	8 applications	None				
	5	"	"	"	"	"	"		"	"	"				
	6	"	"	"	"	"	"		"	"	"				
	7	"	"	"	"	"	"		"	"	"				
	8	"	"	"	"	"	"		"	"	"				
	8	"	"	"	"	"	"		"	"	"				
5	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	9 applications	None				
	2	"	"	"	"	"	"		"	"	"				
	3	"	"	"	"	"	"		"	"	"				
	4	"	"	"	"	"	"		"	"	"				
	5	"	"	"	"	"	"		"	"	"				
	6	"	"	"	"	"	"		"	"	"				
	7	"	"	"	"	"	"		"	"	"				
7	8	"	"	"	"	"	"		"	"	"				
	—	Steam	1 ton per acre	None	None	None	10 cwt. per acre		5 cwt. per acre	8 applications	1 application				
	1	Steam	1 ton per acre	None	None	None	10 cwt. per acre		5 cwt. per acre	8 applications	1 application				
	4	"	"	"	"	"	"		"	"	"				
	6	"	"	"	"	"	"		"	"	"				
	7	"	"	"	"	"	"		"	"	"				
	8	"	"	"	"	"	"		"	"	"				
9	1	Steam	1 ton per acre	None	None	None	10 cwt. per acre		5 cwt. per acre	8 applications	1 application				
	2	"	"	"	"	"	"		"	"	"				
	3	"	"	"	"	"	"		"	"	"				
	4	"	"	"	"	"	"		"	"	"				
	—	Steam	1 ton per acre	None	None	None	10 cwt. per acre		5 cwt. per acre	8 applications	1 application				
	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	None	5 cwt. per acre	8 applications	1 application				
	2	"	"	"	"	"	"	"	"	"	"				
10	3	"	"	"	"	"	"	"	"	"	"				
	4	"	"	"	"	"	"	"	"	"	"				
	—	Steam	1 ton per acre	None	None	None	10 cwt. per acre		5 cwt. per acre	8 applications	1 application				
	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	None	5 cwt. per acre	8 applications	1 application				
	2	"	"	"	"	"	"	"	"	"	"				
	3	"	"	"	"	"	"	"	"	"	"				
	4	"	"	"	"	"	"	"	"	"	"				
12	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	None	10 cwt. per acre	None	5 cwt. per acre	None	2½ cwt. per acre		None	2½ cwt. per acre	
	2	"	"	"	"	"	"	"	"	"	"		"	"	
	3	"	"	"	"	"	"	"	"	"	"		"	"	
	4	"	"	"	"	"	"	"	"	"	"		"	"	
	—	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	None	5 cwt. per acre	7 applications					
	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	5 cwt. per acre	7 applications					
	2	"	"	"	"	"	"	"	"	"					
Rose House	3	"	"	"	"	"	"	"	"	"					
	4	"	"	"	"	"	"	"	"	"					
	—	Steam	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	5 cwt. per acre	7 applications					
	1	Formaldehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	5 cwt. per acre	7 applications					
	2	"	"	"	"	"	"	"	"	"					
	3	"	"	"	"	"	"	"	"	"					
	4	"	"	"	"	"	"	"	"	"					

APPENDIX "C"

MANURES APPLIED IN PLOTS 1-3 AND 8-10 IN TOMATO HOUSE 4

Plot	Title	Base Manure in Lbs. per sq. yds.				*Top Dressing in Lbs. per sq. yds.		
		Lime	Stable Manure	Super- phos- phate	Sulphate of Potash	Super- phos- phate	Sulphate of Ammonia	Sulphate of Potash
1	Complete Artificials (I) less Nitrogen	1.0	—	0.4	0.1	0.5	—	0.2
2	Unmanured	—	—	—	—	—	—	—
3	Complete Artificials	1.0	—	0.4	0.1	0.5	0.2	0.2
8	Complete Artificials with Dung	1.0	7	0.4	0.1	0.5	0.2	0.2
9	Complete Artificials less Phosphate	1.0	—	—	0.1	—	0.2	0.2
10	Complete Artificials less Potash	1.0	—	0.4	—	0.5	0.2	—

* The Top-dressing was applied in eight equal instalments.

APPENDIX "D"

DATES OF CULTURAL OPERATIONS, 1951

Crop	Sown	Potted into 60's	Potted into 32's	Planted out in Borders	First top Dressing	First Fruit Picked	Last Feed Applied	Last Fruit Picked
Tomatoes	1.1.51	Jan. 23	—	March 6	April 13	May 28	Aug. 17	Nov. 12
Cucumbers	22.1.51	—	Feb. 7	March 6	April 30	April 10	Sept. 24	Oct. 10

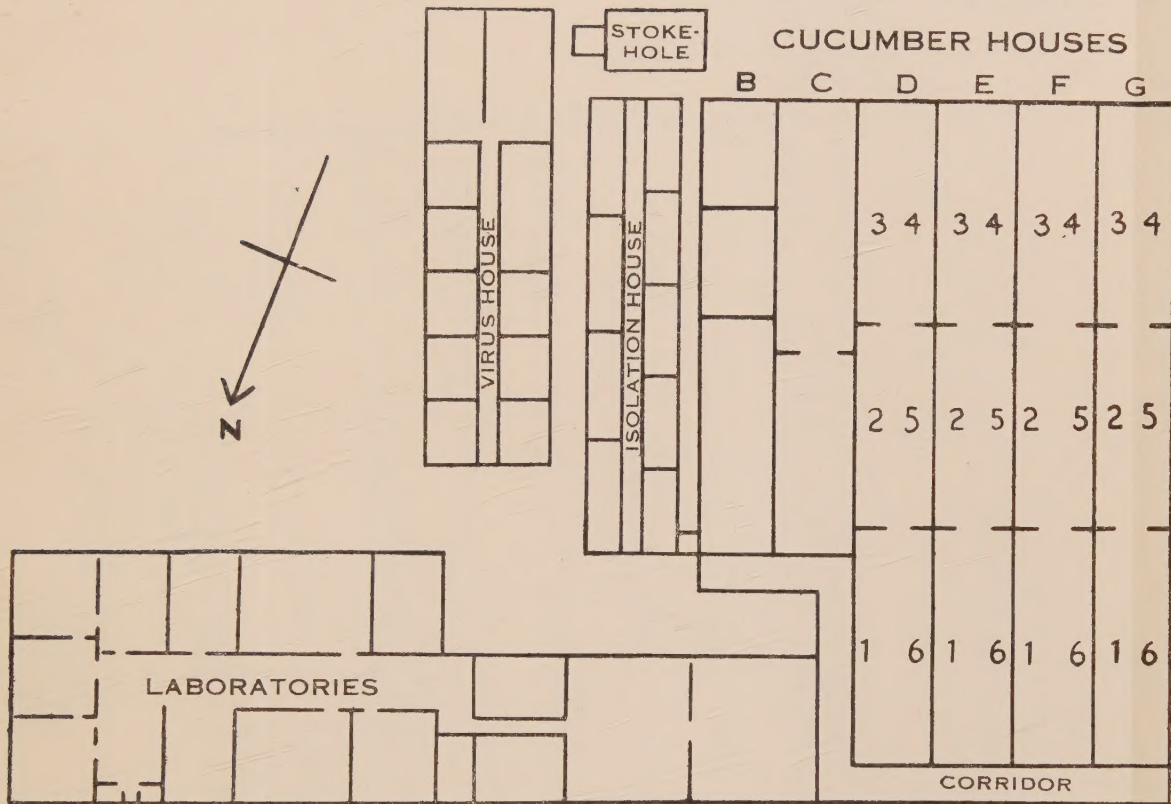
APPENDIX "E" METEOROLOGICAL RECORDS, 1951

Month	Air Temperatures										Rainfall			Mean Soil Temperatures at 9 h. G.M.T.			at 9 hrs. G.M.T. Hygrometer				No. of Days Fog at 9 h. G.M.T. †	Bright Sunshine		
	Mean		Absolute Maximum		Absolute Minimum		No. of Ground Frosts *	Absolute Grass Min.		Total ppt. No. of days ppt.	Greatest Fall		9 h. G.M.T.			Dew Point	Relative Humidity	Depress. of Wet Bulb	Dry Bulb	° F.		° F.	%	
	Max.	Min.	Temp.	Date	Temp.	Date		Temp.	Date		Amt.	Date	4 ins.	8 ins.										
	° F.	° F.	° F.		° F.		° F.				Ins.	Ins.	Ins.	1st	37.4	38.3	40.0	1.1	90.5	37.5				Total Hours
JANUARY	45.1	35.2	54	17th	21	29th	13	15	{ 28th 29th	2.68	21	0.63	1st	37.4	38.3	40.0	1.1	90.5	37.5			9	34.4	1.1
FEBRUARY	44.7	33.7	50	8th	26	1st	14	20	1st	4.99	24	0.69	13th	36.0	37.0	39.2	5.0	88.3	36.2			9	38.6	1.4
MARCH	47.4	35.0	57	22nd	24	31st	16	16	31st	3.09	22	0.63	13th	39.0	39.7	42.0	2.5	80.1	36.1			5	89.4	2.9
APRIL	54.6	36.7	76	25th	29	15th	16	19	15th	2.88	16	0.50	8th	43.9	43.8	47.3	5.6	69.1	37.2			1	175.9	5.9
MAY	59.4	44.2	72	24th	36	{ 5th 12th	4	27	{ 3rd 4th	2.21	19	0.71	26th	50.8	50.2	52.4	3.7	75.3	44.6			0	117.1	3.8
JUNE	69.1	48.4	75	6th	41	{ 8th 9th	0	31	21st	0.56	9	0.26	11th	61.0	59.6	60.4	5.7	67.6	49.9			0	241.9	8.1
JULY	73.5	53.4	82	28th	44	14th	0	34	16th	0.81	10	0.35	12th	65.2	64.1	65.9	6.3	67.4	54.4			0	191.8	6.2
AUGUST	68.8	53.0	77	3rd	45	21st	0	36	{ 17th 23rd	5.44	16	1.70	9th	56.6	58.6	66.4	9.0	74.9	53.7			0	152.2	5.2
SEPTEMBER	67.2	50.9	77	4th	38	22nd	0	31	22nd	3.82	14	1.25	27th	57.5	57.9	59.9	3.6	79.4	53.5			2	102.6	3.7
OCTOBER	58.0	40.9	65	{ 6th 8th	26	24th	13	19	24th	1.12	13	0.14	31st	47.7	49.6	49.3	1.8	87.1	45.5			5	88.8	2.9
NOVEMBER	53.8	41.4	60	6th	29	26th	7	20	26th	4.13	21	0.54	18th	44.9	46.1	48.1	2.1	84.1	43.0			0	54.6	1.8
DECEMBER	48.3	36.4	54	{ 15th 20th 30th	18	13th	13	12	13th	1.54	15	0.30	28th	29.9	41.1	42.1	1.6	86.6	38.2			6	54.0	1.7
TOTAL	...	...	...	...	...	...	96	...	...	33.27	200	...	...	...	...	...	...	...	...	...	37	1341.3	...	

* Grass Min. 30-4° F. or less.

† Visibility 440 yards or less.

DIAGRAM SHEWING ARRANGEMENT



No
6
5
4
3
2
1

NT OF EXPERIMENTAL PLOTS, 1951

TOMATO HOUSES

